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U. S. COMMISSION OF FISH AND FISHERIES,

GEORGE M. BOWERS, Commissioner.

ARTIFICIAL PROPAGATION

OF THE

SALMONS OF THE PACIFIC COAST.

Extracted from the Revised Edition of the Fish Manual.
Pages 1 to 15, Plates 3 to 10.

WASHINGTON:
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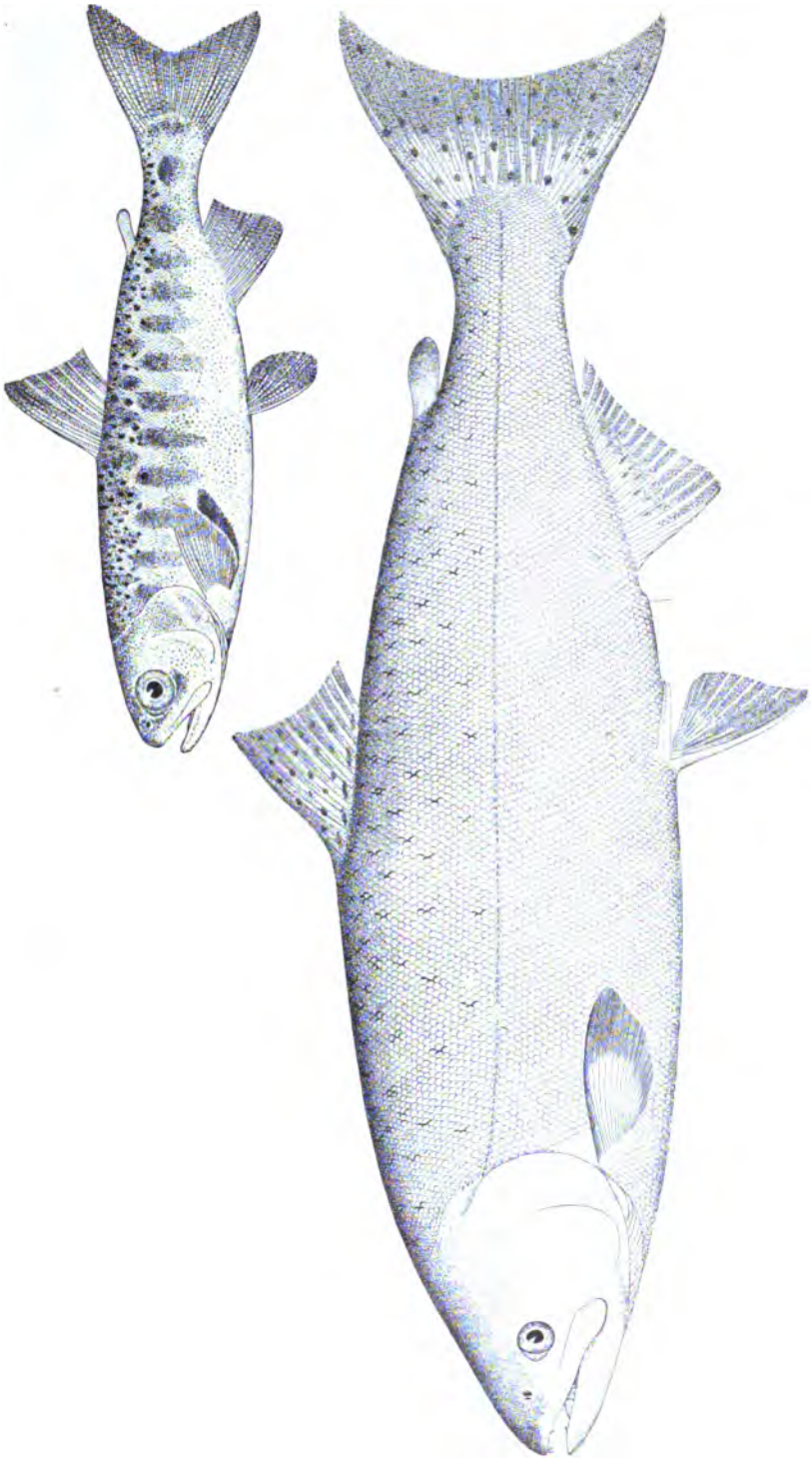
1903.



ONCORHYNCHUS TSCHAWYTSCHA *Quinnat Salmon; Chinook Salmon; King Salmon.*
The upper figure is drawn from a young example, 4 inches long.

THE SALMONS OF THE PACIFIC COAST.

There are five species of salmon on the Pacific coast which belong to the genus *Oncorhynchus*, namely, the chinook or quinnat salmon (*Oncorhynchus tschawytscha*), the red or blueback salmon (*Oncorhynchus nerka*), the humpback salmon (*Oncorhynchus gorbuscha*), the silver salmon (*Oncorhynchus kisutch*), and the dog salmon (*Oncorhynchus keta*). The features which separate the Pacific salmons from the Atlantic salmon are not marked and consist chiefly in a larger number of rays in the anal fin, and more branchiostegals, gillrakers, and pyloric cœca.

The characters noted in the following key will usually be sufficient to distinguish the different species of Pacific salmon:

Quinnat salmon: Scales in longitudinal series from 135 to 155, averaging about 145; pyloric cœca 140 to 185; gillrakers comparatively short and usually 23 in number, 9 being above the angle; rays in anal fin 16; branchiostegals 15 to 19. Body robust; head conic; eye small; caudal fin deeply forked. Color above dusky, sometimes with bluish or greenish tinge; sides and belly silvery; head dark, with metallic luster; back and the dorsal and caudal fins with numerous round black spots.

Blueback salmon: Scales in longitudinal series about 130; pyloric cœca, 75 to 95; gillrakers comparatively long and 32 to 40 in number; rays in anal fin 14 to 16; branchiostegals 13 to 15. Body rather slender; caudal fin much forked; anal and dorsal fins low. Color, above bright blue, sides silvery, no spots.

Humpback salmon: Scales very small, 210 to 240 in longitudinal series; pyloric cœca very slender, about 180 in number; gillrakers short, about 28, 13 being above angle; anal rays 15; branchiostegals 11 or 12. Color, bluish above, silvery on sides; hind part of back, adipose fin, and tail with numerous black spots, largest and of oblong form on tail.

Silver salmon: Scales large, 125 to 135 in longitudinal series; pyloric cœca comparatively few and large, 45 to 80 in number; gillrakers long and slender, 23 in number, 13 below angle; anal rays 13 or 14; branchiostegals 13 or 14. Body long; head short, conic; snout blunt; eye small; fins small, caudal deeply forked. Color bluish-green, sides silvery, finely punctulated; spots few and obscure on head, back, dorsal, adipose dorsal, and upper rays of caudal.

Dog salmon: Scales of medium size, 138 to 155 in lateral line; pyloric cœca 140 to 185; gillrakers short and few, 9 above and 15 below angle; 13 or 14 rays in anal fin; branchiostegals 13 or 14. Form of quinnat, but head longer and more depressed. Dusky above and on head, paler on sides; very fine spots on back and sides, often wanting; tail plain dusky or finely spotted, with black edge; other fins blackish.

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These salmons are the most important group of fishes entering the rivers of North America. The steelhead (*Salmo gairdneri*), technically a trout, but popularly regarded as a salmon, also inhabits the waters of the Pacific coast and adds to the importance of the salmon tribe.

In recent years the annual catch of salmon in the Pacific States and Alaska has been over 100,000,000 pounds. In 1899 the quantity of salmon canned was 2,450,000 cases of 48 one-pound cans. The weight of the fresh fish represented by this pack, together with the large quantities sold fresh, salted, and smoked, was about 175,000,000 pounds, with a value, as placed on the market, of nearly $9,000,000.

THE QUINNAT SALMON.

The quinnat salmon (*Oncorhynchus tschawytscha*) is known by a number of other common names in various parts of its range; among them are chinook salmon, king salmon, Columbia salmon, Sacramento salmon, and tyee salmon. The quinnat is the most important of the salmons. It is not only superior in food qualities, but attains a vastly larger size, has a wider geographical range and a greater commercial value than any of the others. When fresh from the ocean it is a very handsome, resplendent, well-formed fish, greatly resembling the Atlantic salmon (*Salmo salar*), although its form is less symmetrical and its outlines less graceful. It is of a uniform rich red color, becoming paler or streaked upon the approach of the spawning season. Its value for canning purposes is largely enhanced by the persistence of the red color of the meat after cooking.

In size no other salmon in the world compares with it. In the Yukon River, Alaska, it reaches a weight of over 100 pounds, and in the Columbia River there are well authenticated cases of its weighing more than 80 pounds. Farther south, it runs smaller, although in the Sacramento individuals weighing 50 or 60 pounds are not rare; 22 pounds is a fair average weight in the Columbia River and 16 pounds in the Sacramento.

Its known range is practically from Monterey Bay (latitude 36½) to the Yukon River, but individuals have been seen in Norton Sound, somewhat north of the Yukon, and as far down the coast of California as the Ventura River. Since it thrives well in very cold water it is likely that its range extends to and possibly within the Arctic Ocean.

While in the sea quinnat salmon probably do not wander very far from the mouths of the rivers they have left, and for this reason usually return to spawn in the rivers in which they were hatched. They prefer the larger rivers, like the Sacramento, the Columbia, the Nushagak, and Yukon. They are very persistent in ascending the rivers to spawn, and have been seen crowding up the rivulets which form the head waters of the Sacramento until nearly half their bodies were exposed to the air. No matter how far the headwaters of a river are from the ocean, some of the salmon will press forward until stopped by impassable obstructions or water too shallow for them to swim in. On reaching

the headwaters they remain for a week or two before proceeding to the spawning-grounds. Their rate of progress varies with the season, and probably depends to a great extent on the rainfall and the state of the river, rain, roily water, and high water always hastening their progress.

When they first come from the ocean the sexes are almost identical in appearance, but as the time for spawning approaches a difference is noticed between the males and the females, which during the spawning season becomes more marked. The fully developed ova of the female give her a round, plump appearance, while the male grows very thin. His head flattens, the upper jaw curves like a hook over the lower, the eyes become sunken; large, powerful, white, dog-like teeth appear on both jaws, and the fish acquires a gaunt and savage appearance. As soon as they reach fresh water their appetites grow less, their throats begin to narrow, and their stomachs to shrink. This does not at first entirely prevent them from feeding, but it changes them enough to enable them to overcome the temptation to return to their well-stocked feeding-grounds in the ocean, and the longer they remain in fresh water the greater are the changes, and the desire to turn back for food is correspondingly lessened. This change comes about gradually, increasing day by day from the time they leave tide water until at the near approach of the spawning season their throats and stomachs become entirely incapacitated for receiving food, and the desire and ability to feed leave them entirely. The great reserve of flesh and blood which they bring with them from the ocean enables them to keep the vital organs active until their mission up the fresh-water streams is accomplished.

Quinnat salmon that spawn a long distance from the ocean do not return to it again, but die on or near their spawning-grounds. This singular fact has been disputed, but its truth has been proved repeatedly and conclusively. After spawning they rapidly deteriorate, the flesh shades off to a light, dirty pink and they become foul, diseased, and much emaciated. Their scales are wholly absorbed in the skin, which is of a dark olive or black hue, and blotches of fungus appear on their heads and bodies, and in various places are long white patches where the skin is partly worn off. Their fins and tails become badly mutilated, and in a short time they die exhausted.

The quinnat salmon first appear on the Pacific coast at Monterey Bay, where many are caught with hook and line as early as the second week in January, and are next seen in the Sacramento River in numbers in February. In the Columbia River they appear in March, but are not abundant until April or May. They arrive in southern Alaska in May and farther north in June, while it is probable that it is still later before they ascend the Yukon, where the running season is very short and may not exceed a month or six weeks. The early runs in the Columbia River are usually from one to three weeks passing from the mouth of the river to Clifton, about 20 miles. They first appear at The Dalles, 200 miles up the river, in the middle of April, and are found

in great quantities at this point about the middle of June, two months after they appeared in large numbers at the bar. This would indicate that they proceed up the Columbia at the rate of 100 miles a month. In the later runs they probably travel faster.

The spawning season of the quinnat varies in different rivers and, considering the entire coast, lasts at least six months. In July the summer run is spawning at the headwaters of the McCloud and Sacramento rivers in California; in August and September, farther down these rivers. In October the fall run has begun in the McCloud and below and this run continues spawning through November into December. In the Columbia the spawning begins at the headwaters in June; at Clackamas, 125 miles from the mouth of the river, it begins about the middle of September and continues until November.

A few days before they are ready to spawn the salmon hollow out elongated cavities with their heads and tails in the gravel beds of the river where there is some current, and here in due time the eggs and milt are deposited. The eggs drift into the crevices in the pile of stones thrown up below the hollow, sink to the bottom, and remain in that protected position during incubation; here, also, the young remain until the umbilical sac is absorbed. The eggs and young are liable to destruction by freshets, but are comparatively safe from other injurious influences.

The quinnat is not so prolific as the Atlantic salmon, 300 or 400 eggs to each pound weight of the parent fish being a fair average.

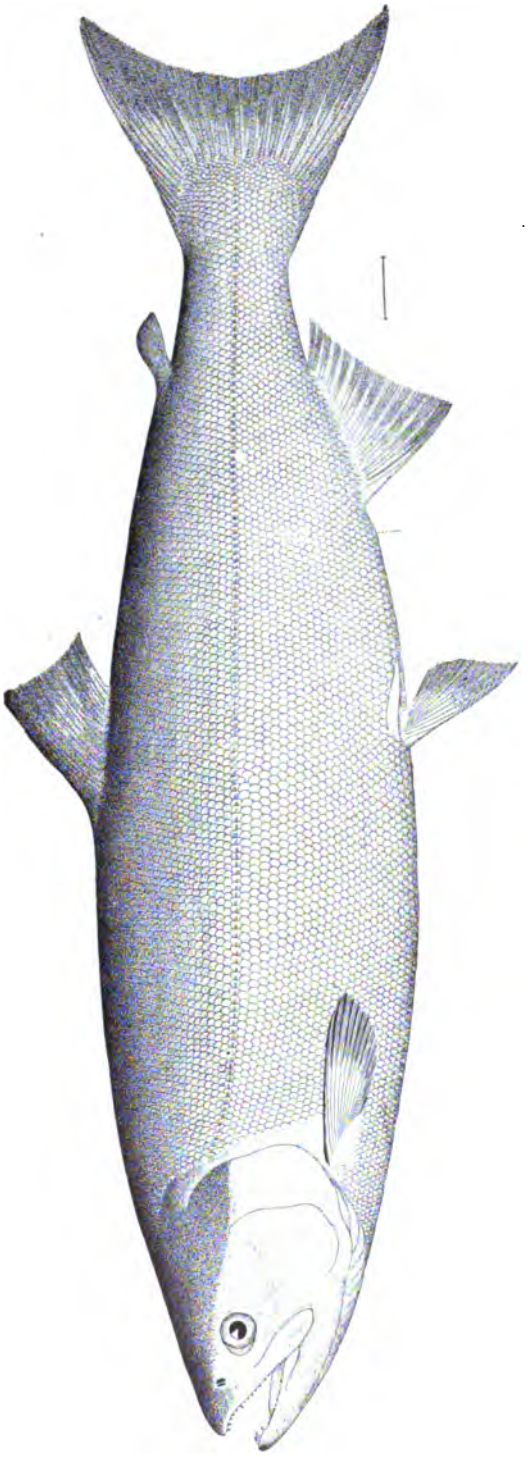
In view of the enormous annual catch of this salmon for commercial purposes the necessity for its propagation became manifest at an early period in the history of the Pacific fisheries. Fortunately it is readily susceptible of artificial propagation on a large scale, otherwise the supply in the western rivers would have materially fallen off. Since the work began in 1873 on the McCloud River it has grown to large proportions, and engages the attention of all the coast States as well as the General Government, and is now more extensive than ever before.

As the salmon ascend the rivers they are caught by gill nets, fyke nets, pounds, weirs, seines, wheels, and other devices, but in the Sacramento and Columbia the greater numbers are caught with gill nets drifting with the current or tide as they head upstream. In the rivers they are comparatively safe from enemies except otters, ospreys, and fishers, but immense numbers are destroyed at the mouths of the streams by seals and sea lions.

The quinnat salmon has been introduced into Japan, Australia, New Zealand, and Europe, but efforts to acclimatize it on the Atlantic coast of the United States have so far been unsuccessful.

THE BLUEBACK SALMON.

Considering the entire west coast, this species (*Oncorhynchus nerka*) is probably more numerous than all the other salmons combined. It is known in different regions under the names blueback, redfish, red salmon, Fraser River salmon, and sock-eye or saw-qui. It ranks next



ONCORHYNCHUS NERKA. *Blueback Salmon; Redfish.*

to the chinook in commercial value, being especially important in the Columbia and Fraser rivers and in Alaska. For canning purposes it is but little inferior to the chinook, the color of the flesh being a rich red, which persists after canning. Large quantities are canned in British Columbia and in Alaska, particularly on Kadiak Island, and its commercial importance to that Territory is indicated by the fact that nearly half of the entire salmon pack of the world comes from Alaska and the majority of the fish there canned are of this species. Comparatively few red salmon are sold fresh in the United States.

It is next to the smallest of the salmons, the maximum weight being about 15 pounds, but it rarely weighs over 8 pounds and the average is scarcely 5 pounds. In various lakes this fish weighs only half a pound when mature, and is called the little redfish.

It ranges from Humboldt Bay, California, to the far north. In general it ascends only those rivers which rise in cold, snow-fed lakes. No more is known of its ocean life than of the quinnat. It appears in the Columbia with the spring run of the quinnat. In southern Alaska and at Kadiak Island it comes in numbers in June; the heaviest run is in June and July, the spawning occurring in August and September. In the Idaho lakes, which may be considered typical spawning-grounds for this fish in the United States, the height of the spawning season is from August 25 to September 5, although ripe eggs have been found as early as August 2, and fish with eggs in them as late as September 11. In the numerous affluents of the Fraser River the spawning extends from September 15 to November 15, a few stragglers spawning as late as November 30. They deposit their eggs on gravel in rather shallow water, usually in the inlets of the lakes. The eggs average about 1,000 to 1,200 to the fish.

Except in the breeding season the color of this fish is a clear bright blue above, with silvery sides and belly. At the spawning period the back and sides become red, and the male develops an extravagantly hooked upper jaw.

THE HUMPBACK SALMON.

The humpback salmon (*Oncorhynchus gorbuscha*) is the smallest of the Pacific salmons; its average weight is only 5 pounds, and it rarely reaches 10 pounds. Its range is from San Francisco probably as far north as the Mackenzie River, and it is also common on the Asiatic coast. It is the most abundant and generally distributed salmon in Alaska, but in the Pacific States it does not ordinarily occur in great abundance, although there is sometimes a noteworthy run in the Puget Sound region.

In food qualities the fresh-run humpback is scarcely inferior to any other salmon. While the flesh has a very fine flavor, it is paler than that of other red salmon, and the species has consequently been neglected by canners; but it is probable that it will eventually be utilized for canning purposes, and its excellent qualities when fresh are undoubtedly

destined to give it a great commercial value. Its chief consumption now is by Alaskan natives, who cure large quantities for winter use.

The humpback salmon generally seeks the smaller streams for the purpose of spawning and deposits its eggs a short distance from the sea, sometimes within only a few rods of the ocean. At Kadiak Island, Alaska, where it is often very abundant, it arrives in the latter part of July, the run continuing only a few weeks. Spawning takes place in August.

There are only a few hundred eggs to each fish, the eggs being smaller than those of the quinnat but larger than those of the redfish, and paler in color than the eggs of either of those species.

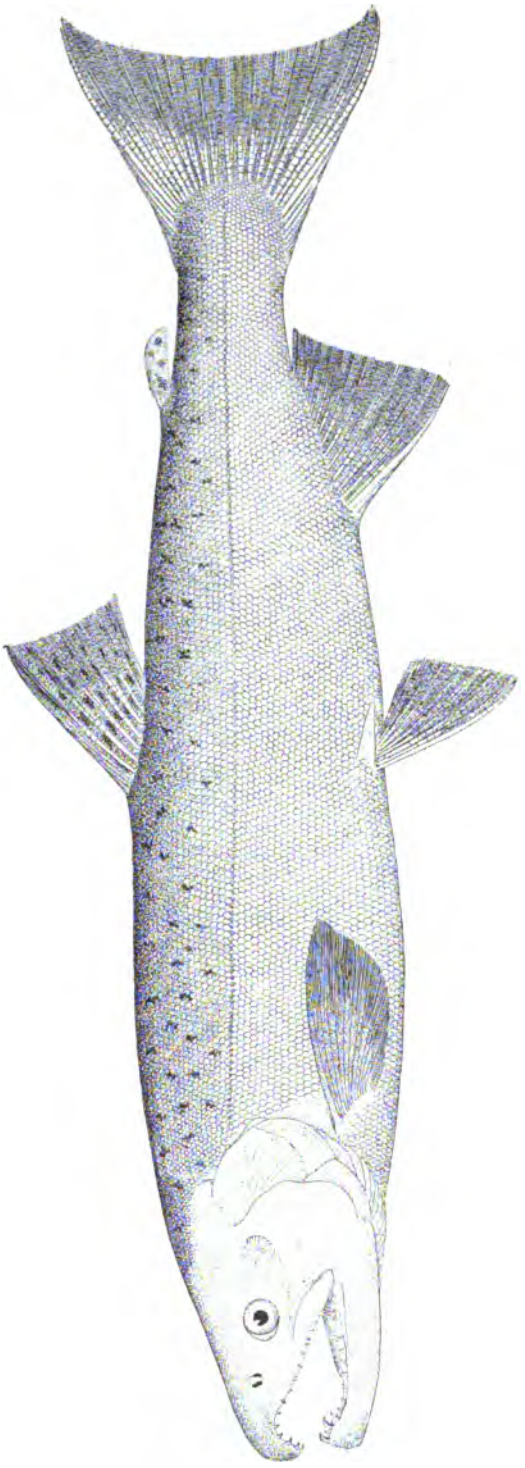
When this salmon first comes from the ocean it resembles a small quinnat, but as the spawning season advances it develops a very large and prominent hump on its back. This, with the distortion of the jaws, gives the fish a very singular appearance. The extreme emaciation and the extensive sloughing of the skin and flesh, which are incident to spawning, result in the death of all the fish, either on the spawning-ground or after being swept out to sea by the current.

THE SILVER SALMON.

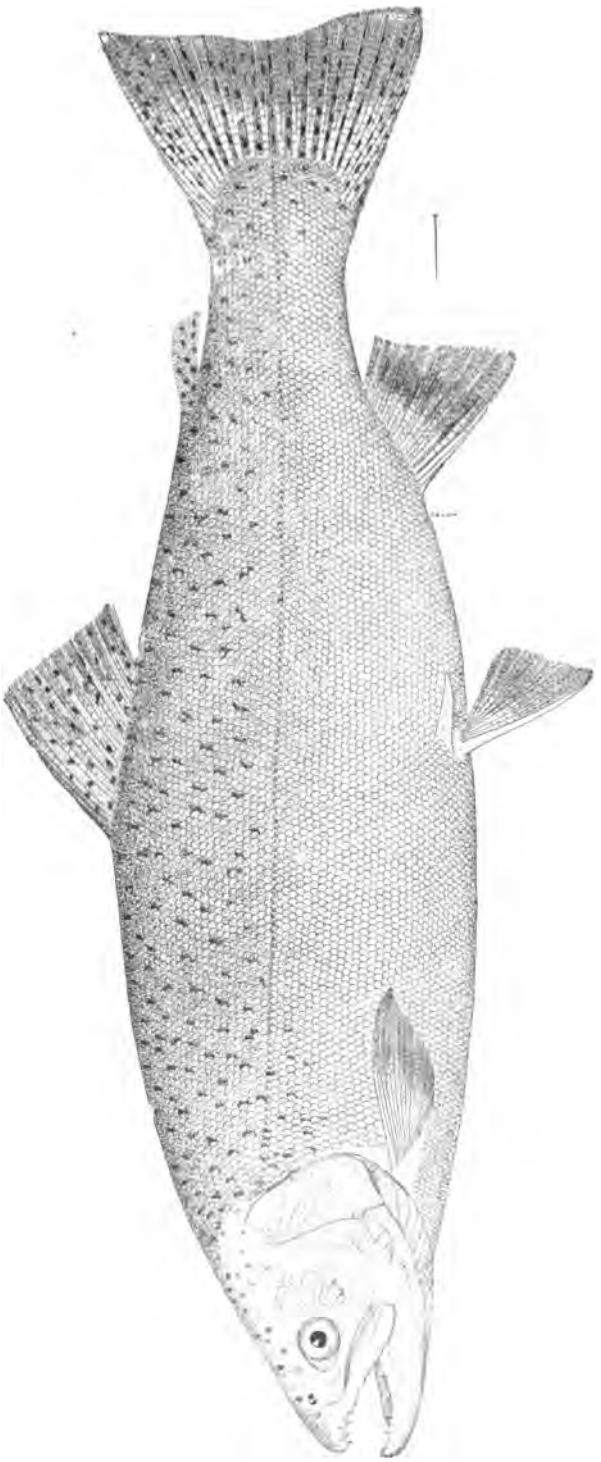
The silver salmon (*Oncorhynchus kisutch*) is also known as silversides, skowitz, kisutch, hoopid salmon, and coho salmon. It is a beautiful fish, having a graceful form and a bright silvery skin. Its flesh, which is fairly good, usually has a bright red color, but as this fades on cooking it is not highly regarded for canning purposes, though large quantities are thus utilized on the Columbia River, Puget Sound, and the short coast streams of Oregon and Washington. Its average weight in the Columbia and Puget Sound is 8 pounds, but in Alaska it averages nearly 15 pounds; it rarely reaches 30 pounds. Its range is from San Francisco to northern Alaska, and as far south on the Asiatic coast as Japan. It runs up the rivers to spawn in fall or early winter, when the waters are high, but usually does not ascend great distances from the ocean. The average number of eggs to a fish is about 2,000.

THE DOG SALMON.

The dog salmon (*Oncorhynchus keta*) is the least valuable of the Pacific salmons, although it is dried in large quantities by the Alaskan natives. Its average weight is 12 pounds and the maximum is about 20 pounds. It is found from San Francisco to Kamchatka, being especially abundant in Alaska. The enlargement and distortion of the jaws give the species a very repulsive look, and the large teeth give to it its common name. When just from the ocean, the flesh has a beautiful red color and is not unpalatable, but it deteriorates rapidly in fresh water. It spawns in shallow rivers and creeks. Larger quantities are utilized in Puget Sound than elsewhere in the Pacific States, and it is also used considerably by the natives of Alaska.



ONCORHYNCHUS KISUTCH. *Silver Salmon.* Breeding male, with distorted jaws.



SALMO GAIRDNERI. *Steelhead.*

THE STEELHEAD.

Another anadromous salmonoid fish found on the Pacific coast, popularly regarded as a salmon, is the steelhead (*Salmo gairdneri*), known also as hardhead, winter salmon, square-tailed trout, and salmon trout. It resembles in form, size, and general appearance the salmon of the Atlantic coast, and is distinguished from other Pacific coast salmon by its square tail, its small head, round snout, comparatively slender form, light-colored flesh, and its habit of spawning in spring. It is more slender than the quinnat and consequently not so heavy for its length. Its average weight in the Columbia is about 10 pounds, although it sometimes reaches 30 pounds.

Its range is very extended, reaching from Santa Barbara on the southern coast of California to the Alaska Peninsula, and perhaps to the Arctic Ocean, and it is found in almost all the streams of the Pacific States which empty into the ocean. It begins to enter the Columbia in the fall, and is then in prime condition. From this time it deteriorates until the following spring, when, between the months of February and May, spawning occurs. Its movements in other rivers on the coast are not materially different, though perhaps it enters the southern rivers earlier and northern rivers later than the Columbia. Like the chinook, the steelhead ascends rivers for long distances, and it has been found almost as far up the tributaries of the Columbia as the ascent of fish is possible. Its eggs are much smaller than those of the chinook and average 3,000 to 5,000 to the fish.

As the greatest quantities of steelheads are caught in the spring, when they are spawning and are in a deteriorated condition, they are not generally esteemed as food; but when they come fresh from the sea and are in good condition, their flesh is excellent. As the demand for salmon has increased, steelheads have been utilized for canning and they have formed a noteworthy part of the canned salmon from the Columbia River for a number of years past, as well as from the short coast rivers of Washington and Oregon. Their consumption fresh has been increasing yearly and considerable quantities have been sent to the Eastern States in refrigerator cars.

ARTIFICIAL PROPAGATION.

The chinook being the principal salmon that has been propagated artificially, the present chapter relates almost entirely to this species. The discussion of the apparatus and methods has special reference to the hatcheries of the Commission on McCloud River and Battle Creek, tributaries of the Sacramento, although cognizance is also taken of the work at the stations in the basin of the Columbia River and on the short coast rivers of California and Oregon.

In 1899 the number of eggs of this fish collected by the Commission was 48,043,000, from which about 43,775,000 fry were hatched and planted. The collections of steelhead eggs numbered 415,000, which produced 85,935 fry.

CAPTURING ADULT SALMON.

The eggs used for artificial propagation are obtained from salmon taken on their way upstream to the natural spawning-grounds. The ascent of the fish is stopped by a heavy wooden rack or barricade and below this obstruction their capture is effected by various means depending on the natural conditions. At Baird station, on the McCloud River, the most practical method of collecting them in large numbers is with drag or sweep seines. These are from 120 to 170 feet long, made of about 28-thread twine, and are 20 feet deep in the middle, tapering down to about 6 feet at the ends; they are double-leaded on account of the swift current of the river, and have a 4-inch mesh.

In the rack are built large wooden traps, in which at times (especially during a rain storm accompanied by a marked rise in the river) large numbers of salmon are taken, but there is never more than a small percentage of spawning fish thus secured. The trap is simply a square inclosure of vertically placed slats, with an entrance similar to that of an ordinary pound net. The fish, in their eager efforts to pass upstream, go through the V-shaped mouth of the trap, and having once entered are not able to find their way out. Boards are placed over the top of the trap to prevent the fish from leaping out.

The trap is quite a valuable auxiliary to the seine, but although it will secure many unripe fish, the ripe ones, which are the ones wanted, finding an obstruction in their way, are apt to settle back to spawning-grounds below and remain there. This may be obviated by building a second rack below the first, which, while permitting the ascent of the fish, is so constructed as to prevent their return.

Large dip nets have been used occasionally at Clackamas station, in Oregon, the fishermen standing on the rack at night and dipping below it. Toward the end of the season this method secures a considerable number of ripe fish, but it involves much labor and expense, and most of the spawning fish taken with the dip nets would probably have been captured in the regular course of fishing. There being no satisfactory seining-grounds at Clackamas, and the river just below the rack being shallow, an Indian method of fishing is used. The aversion of salmon to heading downstream is well known, but when they are very much frightened they will turn around and rush downstream at their utmost speed. The Indians take advantage of this fact and build a dam of rock or wickerwork, or anything that will present an obstruction to the frightened fish. It is shaped like the letter V, with the angle downstream, and at the angle is a large trap into which the fish are driven. This was at one time the principal method of capturing the breeding salmon at Clackamas, and it worked very satisfactorily. Fyke nets and other fish-catching devices have been employed from time to time, but have been rejected as unsatisfactory.

At Baird, before the rack was employed permanently, seine fishing was usually begun after dark and continued throughout the night, but

RACK FOR STOPPING ASCENT OF SALMON, AT BATTLE CREEK, CALIFORNIA.

since the rack has been in use the seine has been hauled more or less in the daytime with perfectly satisfactory results, the fishing generally commencing about 4.30 a. m. and continuing as long as the results warrant it. The work is resumed again about 5 o'clock in the afternoon and continued as long as it meets with success.

CONSTRUCTION OF THE RACK.

This obstruction consists of a fence placed across the river and supported by piers heavy enough to prevent the force of the current from pushing them out of position. Log stringers, from 8 to 15 inches in diameter, are laid from pier to pier, to which they are securely pinned, and posts, from 2 to 4 inches in diameter and of the required length, are driven obliquely into the bed of the river, the lower ends being 3 or 4 feet upstream, the upper ends resting on the stringers. Against these posts is laid the rack, which is made in sections, each 6 to 10 feet long, the slats which form them being 1¼ inches thick and 3 inches wide, and securely braced at top and bottom. The slats are set 1½ inches apart, and are beveled on the upper side in order to present less resistance to the current. The space between the slats allows ample room for water to go through, but prevents any salmon from ascending. A wider space between the slats would be preferable, as creating less obstruction to the current, but it would allow a considerable percentage of small grilse (the young salmon after its first return from the sea) to get by the rack, and unless the older males are quite plentiful the grilse are likely to be needed when the spawning season arrives.

The piers, when first made, are hollow triangles of heavy logs, each layer of logs being firmly pinned to the one below it, until the required height is reached, the apex of the triangle pointing upstream. They are afterwards filled with rocks and are very substantial. Those on the McCloud have been able to withstand the tremendous momentum of the current, even in the highest water.

TAKING AND IMPREGNATING THE EGGS.

After salmon are secured by the seine or other means, they are, for convenience in handling, placed in pens or live-boxes made for this purpose, the ripe or nearly ripe males and females being kept separate. Where the eggs are taken on a large scale, it is desirable to have separate compartments for ripe males, ripe females, nearly ripe females, and males partially spent that it may be necessary to use again, and one or two spare compartments are found to be convenient where large numbers of fish are handled.

Stripping the fish is usually done every day, as the eggs of the females confined in the pens are likely to be injured within the fish, which is a serious objection to keeping the parent fish in confinement a. . longer than is absolutely necessary.

Of the signs that usually accompany ripeness in a female salmon, the separation of the eggs in the ovaries is the surest, but the spawn-

taker relies rather on a general appearance which is neither color, shape, nor condition of organs, but which shows at a glance that the fish is ripe and can be appreciated only by experience.

Spawning operations are conducted upon a floating platform, beneath which are compartments for retaining the ripe fish, and which are accessible through hinged covers set in the plank flooring. Projecting beyond this platform is another, upon which the actual work of stripping the fish and caring for the pans is performed.

When taking the eggs, one or two men stand ready with dip nets to hand the females to the spawn-taker, and one or more perform the same office with the males. After the salmon are taken from the pens they are held suspended in the net until their violent struggles are over, after which they become quiet enough to be handled and the eggs and milt can be expressed easily.

All methods of taking salmon spawn are very much the same, there being only slight differences in details, chiefly in the manner of holding the parent fish and impregnating the eggs. Where there are plenty of assistants and the salmon are of medium size, the most expeditious way is for the man who takes the spawn to hold the female in one hand and press out the eggs with the other, another in the meantime holding the tail of the fish. The male is handled in the same way.

The above method is employed at Baird, but on the Columbia River, where the salmon are larger and are harder to manage, the "strait-jacket," as it is called, is used; this is a sort of a trough made about the average length of the salmon and hollowed out to fit its general shape. Across the lower end is a permanent cleat, and at the upper end is a strap with a buckle. The fish, when manipulated, is slid into the trough, the tail going down below the cleat, where it is securely held, and the head is buckled in at the upper end with the strap. It is now unable to do any harm by its struggles and the eggs can be pressed out at leisure. The strait-jacket is almost indispensable with the very large salmon and is a very great convenience when the operators are limited in number.

In impregnating the eggs the main object is to bring the milt and the eggs together as quickly as possible after they have left the fish. By some persons a little water is considered desirable to give greater activity to the milt, but if left more than a minute in the water there is a decided loss of fertilizing power. The eggs do not suffer so quickly from immersion in water. The absorbing property which they possess when they first leave the parent fish, and which attracts to the micropyle the spermatozoa, lasts several minutes, but it is not prudent to leave the eggs in the water a moment longer than is necessary before adding the milt.

The addition of the water is not essential to a good impregnation; in some instances better results are secured without the use of water and, after all, if the main object is secured, of bringing the milt and

PLATE 8.

TAKING SALMON EGGS AT LITTLE WHITE SALMON STATION.

FERTILIZING SALMON EGGS.

SALMON IN STRAIT-JACKET.

the eggs together with the slightest possible delay after they leave the fish, it makes very little difference whether water is used or not. The milt retains its fertilizing power several days when kept from air and water, and impregnation can be effected between fishes widely separated by merely forwarding the milt properly sealed. At Baird impregnation by the dry method, which has always been followed there, has resulted in the fertilization of about 90 per cent of the eggs so treated.

The Russian or dry method of impregnating eggs consists simply in taking both the eggs and the milt in a moist pan. It may be urged as an objection to this method that the eggs will be injured by striking against the pan, but it is a fact that although the same eggs would be destroyed by the concussion a week later, or even 24 hours later, they do not suffer in the least from it at the moment of extrusion from the fish.

It was at one time considered an important question whether the eggs or milt should be taken first, but with the dry method it makes no difference, as, either way, both eggs and milt remain operative long enough for all practical purposes of impregnation.

Various methods of treating the eggs in the pan after impregnation has taken place have been tried. Some operators leave the eggs in the pans as first taken with the milt for two or three minutes and then add water, after which they are left to stand in the pan until they separate, when they are washed clean, taken to the hatching-house, and placed in the troughs. Others pour the contents of the several pans—eggs, milt, and all—into a large can after the eggs become impregnated, and when the eggs separate the contents of the can are poured into the hatching-troughs, trusting to the current in the troughs to wash the milt from the eggs. At Baird, water is poured on the eggs a few moments after they become impregnated, after which they are left perfectly quiet until they separate, which in water of the temperature of the McCloud River in September, 52° to 53°, takes about an hour. The pans, in the meanwhile, are put in a trough filled with river water to keep them from becoming too warm. After the eggs separate they are carefully washed and are carried in buckets to the hatching-house, where they are measured and placed in the hatching-trays.

The methods of taking and fertilizing eggs at Clackamas are as follows: The female fish to be operated upon is taken from a floating pen and is placed in the spawning-box or "strait-jacket"; a male fish is then caught and tied with a small rope around its tail to some part of the corral where he can be quickly caught when needed. One man presses the eggs from the female securely held in the spawning-box, the pan for receiving these being held by another. As soon as the eggs are taken, the male is drawn from the pen by the rope and held by one man, who takes it by the tail with his left hand, its head between or across his knees. With his right hand the milt is then pressed from the fish into the pan containing the eggs as soon as possible after they are taken.

The eggs are taken in a pan without any water and milt enough is used to insure its coming in contact with each egg. After the eggs and milt are obtained the pan is gently tilted from side to side and the mass of eggs and milt stirred with the fingers until thoroughly mixed. The pan is then filled about two-thirds full of water and left until the eggs separate, the time varying from 1 to 1½ hours, according to the number of eggs and the condition of the atmosphere.

The eggs of the quinnat salmon are of a deep salmon-red color and are heavier than water. In size they average about $\frac{4}{16}$ or $\frac{5}{16}$ of an inch, from 12 to 18 being covered by a square inch. The number in a quart is about 3,700. Probably 90 per cent of the eggs taken are impregnated on an average, though the results vary with different seasons, places, and methods of handling.

HATCHING APPARATUS AND METHODS.

The hatching apparatus generally employed on the Pacific coast in salmon propagation consists of a combination of troughs and baskets. The troughs in common use are the so-called "Williamson troughs," which are 16 feet long, 12 or 16 inches wide, and 6½ inches deep. The troughs are arranged in pairs, and usually two or three pairs are placed end to end on different levels. The fall of water in each trough is 1½ inches. The troughs are divided by double partitions of wood or metal into compartments just enough longer than the baskets to enable the latter to be raised and lowered and to be tilted slightly. The essential feature of these troughs is that at the lower end of each compartment a partition, extending entirely across the trough, reaches from the bottom almost to the top, and another similar partition at the upper end of the compartment reaches from the top almost to the bottom of the trough, each set of partitions being about an inch apart. The water is consequently forced to flow under the upper partition and over the lower partition, and to do this it must necessarily ascend through the tray of eggs. The troughs are provided with canvas covers stretched upon light frames, and made sunlight proof by saturation with asphaltum varnish, and their interiors are thickly coated with asphaltum.

The egg receptacles are wire trays or baskets about 12 inches wide, 24 inches long, and deep enough to project an inch or two above the water, which is 5 or 6 inches deep in the troughs in which they are placed. Into each of these baskets 2 gallons of salmon eggs, equivalent to about 30,000, are poured at a time. The eggs suffer no injury whatever from being packed together in this manner, the water being supplied in a way that forces it through the eggs, partially supporting and circulating through them. The meshes are too small to permit the eggs to pass through, although the fry are able to do so.

The advantages of this apparatus and method are:

(1) The top of the tray or basket is out of the water and always entirely dry; consequently, in handling it, the hands are kept dry.

PLATE 9.

PENS FOR HOLDING RIPE FISH, AND STRIPPING PLATFORM, AT BATTLE CREEK, CALIFORNIA.

(2) By tilting one end of the tray up and down a little or by lifting it entirely and settling it gently back again in its place the bad eggs will be forced to the top; thus a feather is not required in picking over the eggs and the injuries very often inflicted with it are avoided.

(3) The top of the tray being above water, the eggs can never run over the top nor escape in any way, which is a great advantage over the shallow form of tray.

(4) There is economy of space; 30,000 to 40,000 eggs can be placed in each basket, provided a sufficient quantity of water is available. Two troughs, 16 feet long and 1 foot wide, will by this method carry about 500,000 salmon eggs. The deep trays may be filled at least half full of eggs, and thus ten times as many eggs can be hatched in the same space and with the same supply of water as by the old method. A good but gentle circulation is continually maintained through the eggs.

(5) The deep-tray system is admirably adapted to getting rid of mud that has collected on the eggs, for all sediment accumulating about them can be easily removed by gently moving the tray up and down a few times in the water; but if the deposit of mud on the troughs becomes so excessive as to be unmanageable, a false bottom of wire cloth or perforated zinc can be placed in the troughs at a suitable distance above their real bottom, leaving a space of about 1 or 1½ inches between the wire cloth and the trough bottom. By this means the mud that comes into the trough will sift down into the space below the wire cloth entirely out of the way of the fish, the movements of the fish themselves helping very much to produce this result. Should the accumulation of mud in the space below the false bottom of the trough become too great, it can easily be sluiced out in various ways.

When quinnat-salmon eggs are simply to be matured for shipment, hatching trays with ¼ or ⅕ inch square mesh will answer the purpose, but when the eggs are to be hatched in them, every alternate strand of wire running lengthwise, or, better still, every second and third thread should be left out in order to form an oblong mesh through which the newly hatched fry, after separating themselves from the unhatched eggs, can escape from the hatching trays into the trough below.

At Baird eggs kept in water averaging about 54° F. hatch in 35 days. The allowance of 5 days' difference in the time of hatching for each degree of change in the water temperature is approximately correct.

For the first few days the eggs of the quinnat salmon are very hardy, and at this time they should be thoroughly picked over and the dead ones removed as far as possible before the delicate stage during the formation of the spinal column comes on, so that during that critical period they may be left in perfect quiet. As soon as the spinal column and the head show plainly, the eggs are hardy enough to ship, but when there is time enough it is better to wait a day or two until the eye-spot is distinctly visible, after which time the eggs will stand handling and may be safely shipped if properly packed.

PACKING EGGS FOR SHIPMENT.

The packing-box used in shipping salmon eggs is made of ½-inch pine, 2 feet square and 1 foot deep. At the bottom is placed a thick layer of moss, then a layer of mosquito netting, then a layer of eggs, then mosquito netting again, then successive layers of moss, netting, eggs, netting, and so on to the middle of the box. Here a firm wooden partition is fastened in and the packing renewed above in the same manner as below. The cover is then laid on the top, and when two boxes are ready they are placed in a wooden crate, made large enough to allow a space of 3 inches on all sides of the boxes. This space is filled with hay to protect the eggs against changes of temperature, and the cover being put on the eggs are ready to ship. In the middle of the crate an open space about 4 inches in depth is left, between the two boxes of eggs, for ice. As soon as the crates arrive at the railway station this space, as well as the top of the crate, is filled in with ice. Recent experiments show that salmon eggs can be packed and safely transported to considerable distances when they are first taken.

CARE OF THE FRY.

The eggs of quinnat salmon, like those of the other *Salmonidæ*, hatch very gradually at first, only a small proportion of fish coming out the first day; but the number increases daily until the climax is reached, when large numbers of young burst their shells in a single day. At this time great care and vigilance are required. The vast numbers of shells rapidly clog up the guard-screens at the outlets of the troughs, which should be kept as free as possible by thoroughly cleansing them from time to time.

In the deep trays the newly hatched fish are mixed with unhatched eggs, and the advantage of the oblong mesh in the bottom of the trays becomes apparent. This mesh is too narrow to allow the eggs to fall through, but the hatched fish, being comparatively long and narrow, easily slip down through the long meshes into the space below. They should be assisted by gently raising and lowering the tray at intervals, care being taken not to raise them out of the water, as at this tender age a slight pressure against the wire of the tray will often produce fatal injuries. On this account too much caution can not be exercised in regard to handling them out of water during the first stages of the yolk-sac period, for the injuries can not be seen at first, and often the death of the fry is the first warning that they have been injured.

After the eggs are all hatched and the young fish are safely out of the trays and in the bottom of the troughs, their dangers are few and they require comparatively little care. Almost the only thing to be guarded against now is suffocation. Even where there is an abundance of water and room, with a good circulation, they often crowd together in heaps or dig down under one another until some of them die from want of running water which is not an inch away from them. The best remedy in such a case is to thin them out.

INTERIOR OF HATCHERY AT BATTLE CREEK, SHOWING SALMON BASKET.

Eight thousand gallons of water an hour is sufficient for ten lines of troughs 64 feet in length, containing altogether a little over 1,000,000 young salmons in the yolk-sac stage. This gives in round numbers 800 gallons of water to each 100,000 fry every hour, or 16⅔ gallons per minute, which is a safe minimum.

FEEDING AND PLANTING THE FRY.

When the yolk-sac has become nearly absorbed the fish rise from the bottom of the trough, where they have previously remained, and begin swimming. They are now almost ready for food and must be liberated unless artificial food is provided. As a rule the fry are planted about the time the yolk-sac is absorbed. This is regarded as the best practice, and moreover the amount of space required renders the rearing of fry in large numbers impracticable. They have, however, been successfully retained in troughs in small numbers from the time they begin to feed in February until the middle of May, when on account of the rising temperature of the water they are liberated. They show when they are ready to feed by darting to one side or the other when small particles of food are dropped in the water and floated past them. From this time, for several weeks, the necessity for care and vigilance never ceases. For the first few weeks they should be fed regularly and as often as six times a day, and the earlier in the day the feeding begins and the later it continues at night the better. Two hours after feeding they will be found to be ravenously hungry, and they grow much faster for frequent feeding and get that growth in their infancy which is indispensable to their ultimately attaining the largest possible size. If not fed sufficiently they will bite at one another and cause more or less mortality among themselves.

The best food for salmon fry is some kind of meat, finely pulverized. Boiled liver is especially good for this purpose, partly because it is inexpensive and easily obtainable, and also because it can be separated into very fine particles. Raw liver is also excellent and may be reduced into as fine particles as the cooked liver by grinding or chopping and then properly straining it through a fine-mesh screen. The yolk of boiled eggs is also suitable, but is much more expensive than liver and is not so good for the fish as liver, unless largely mixed with it.

As the fish grow older they continue to thrive best on meat food, but, if that is not always obtainable in sufficient quantities or on account of its expense, a very good substitute is a mixture of shorts or corn meal with the meat. This is prepared as a mush by stirring shorts or middlings into boiling water, a little at a time, so that it will not cook in lumps, but become more of a paste. After it has thoroughly cooked it is allowed to cool and harden. The best proportion is 30 pounds of shorts to 25 gallons of water with 3 or 4 pounds of salt. The percentage of liver to be used in this mixture should be regulated by the age of the fish, feeding the very young fry upon almost a simple meat diet and gradually increasing the proportion of mush.

U. S. COMMISSION OF FISH AND FISHERIES.

GEORGE M. BOWERS, Commissioner.

ARTIFICIAL PROPAGATION

OF THE

ATLANTIC SALMON, RAINBOW TROUT,

AND

BROOK TROUT.

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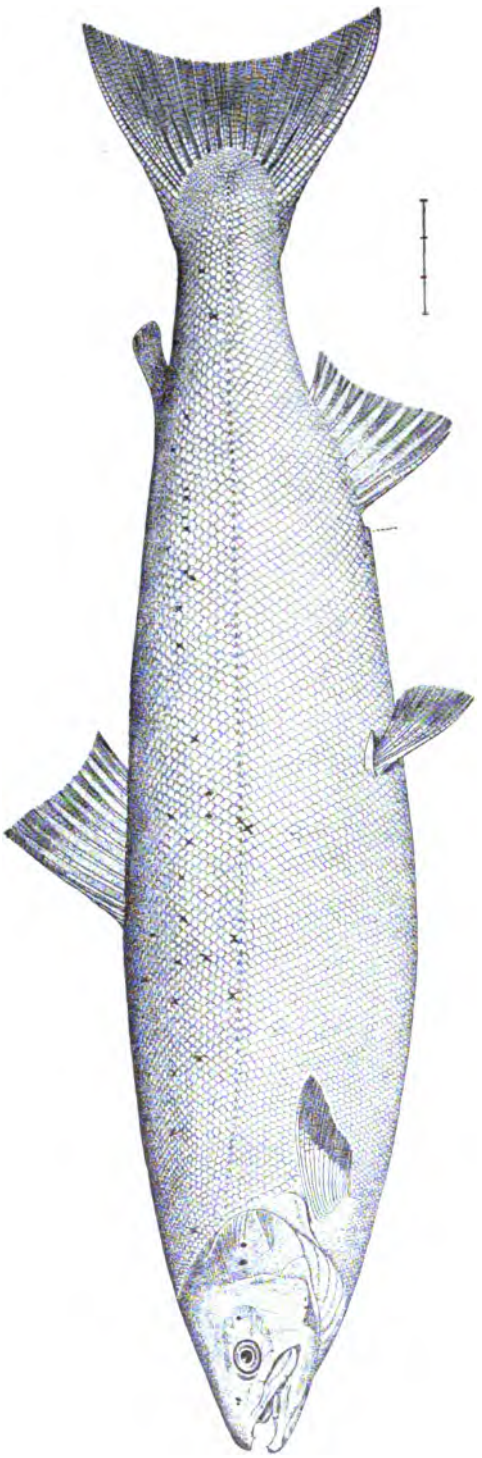


SALMO SALAR. *Atlantic Salmon.*

THE ATLANTIC SALMON

DESCRIPTION OF THE FISH.

The body of the Atlantic salmon (*Salmo salar*) is moderately elongate and but little compressed; the greatest depth is about one-fourth the total length without the caudal fin. The length of the head is about equal to the body depth. The mouth is of moderate size, the maxillary reaching just past the eye, its length contained 2½ or 3 times in the head. The scales are comparatively large, becoming embedded in adult males; the number in the lateral line is about 120, with 23 above and 21 below that line. The dorsal fin has 11 rays and the anal 9 rays. The pyloric cœca number about 65.

The color, like the form, varies with sex, age, food, and condition. The adult is brownish above and silvery on the sides, with numerous small black spots, often x or xx shaped, on the head, body, and fins, and with red patches along the sides in the male. Young salmon (parrs) have about 11 dusky crossbars, besides black and red spots.

RANGE.

The salmon native to the rivers of the northeastern United States is specifically identical with the salmon of Europe and all the affluents of the North Atlantic. Its original natural range in America appears to have been from Labrador or Hudson Bay on the north to the vicinity of New York on the south. Within these limits, at the proper season of the year, it ascended, for the purpose of reproduction, nearly every river except those that did not afford the requisite facilities for depositing spawn or were inaccessible by reason of impassable falls near their mouths.

In American rivers frequented by Atlantic salmon they were found successively in all parts from the mouth upward, their migrations extending nearly to the headwaters of all the branches so far as they were accessible and adapted to their necessities. The one exception is the river St. Lawrence, where it seems probable, from such evidence as is available, that few if any salmon entering the river from the sea ever ascended as far as Lake Ontario, and that the salmon inhabiting that lake and its tributaries have always, as a rule, made the lake their sea and the limit of their downward migrations. Within or partly within the limits of the United States there can be enumerated twenty-eight rivers that were beyond doubt naturally frequented by salmon, beginning with

the St. John and ending with the Housatonic.* In the greater part of these the species has been exterminated by civilized man, and in the few in which it still persists its numbers are far below the estimates which the earliest records warrant us in making for those days.

In certain lakes of Maine and northward this fish is perfectly landlocked and has somewhat different habits and coloration, but no distinct specific characters. Similar landlocked varieties occur in Europe.

LIFE AND HABITS.

Salmon eggs are deposited on coarse gravel on some rapid, generally far up toward the sources of a river, late in October or early in November, when the water is perhaps about 44° F. and the temperature is falling. The egg is impregnated at the moment of its deposit, and the independent life of the salmon begins to develop at once. In a few weeks the embryo becomes sensitive, but the extreme cold of the water retards its development to such an extent that it does not burst the shell of the egg until spring. In the rivers of New England it is probable that nearly all the eggs naturally deposited hatch very late in April and early in May. At this time the embryo salmon has a slender half-transparent trunk, less than an inch in length, carrying, suspended beneath, an immense ovoid sac—the "yolk-sac." For about six weeks after hatching it hides in crevices among stones, keeping up an incessant fanning with its pectoral fins. During this period it takes no food, but is supported and nourished by the yolk-sac, the substance of which is gradually absorbed into the rest of the body, and not until the sac has nearly disappeared does the salmon really look like a fish and begin to seize and swallow food. It now puts on a mottled coat, with several heavy dark bars across its sides, and bright red spots, larger and fewer than those of a trout, looking therefore very unlike the adult salmon but much like a young trout. In this stage it is termed, in Scotland and England, a "parr," and it was formerly thought to be a wholly different species from salmon.

The parr stage lasts a year or two in British rivers, and the few observations made in America indicate that it is more likely two years than one in our rivers. The parr, at first but little over an inch in length, is provided with good teeth and a good appetite, and beginning to feed at a season of the year when the water is almost crowded with small insects and other more minute creatures, it grows rapidly, probably increasing its weight thirty or forty times the first summer. In two years it reaches the length of 6 or 8 inches, and its bright red spots and dark bars have given place to a silvery coat like the adult salmon. It is now termed a "smolt" and is ready to go to sea, which it does with little delay, and passes out beyond the range of man's

*The Hudson River is by some believed to have been a natural salmon river. Its discoverer, Hendrik Hudson, reported having observed them there, and there is nothing inherently improbable in it, but the evidence is perhaps insufficient.

observation, but to a region where it finds a rich feeding-ground and rapidly increases in size.* In northern rivers, those of New Brunswick and beyond, as in those of northern Europe, the salmon returns from the sea when it has attained a weight of 2 to 6 pounds, and is then termed a "grilse."

In the rivers of Canada, in general, grilse occur in great numbers, coming in from the sea at a later date than the adults, but ascending like them to the upper waters, mingling freely with them, rising to the same fly, and caught in the same weirs. The mesh of the nets is limited by law to a size that takes the adult salmon, but allows the grilse to slip through. To this circumstance it is in part owing that by the time the fish have reached those portions of the rivers suitable for angling there is commonly, if it be late enough in the season, a great preponderance of grilse, so that more of the latter than of the former are taken by the angler. In Nova Scotia many grilse are taken in the Shubenacadie River from August until late in the fall. On the Miramichi, in New Brunswick, grilse make their appearance about July 1, and from the middle of that month till the end of August they constitute the main body of the salmon entering the river. Some sportsmen report that the grilse caught exceed the adults in the ratio of 5 to 1.

In the month of August, in the Nepissiguit, Restigouche, and St. John of Gaspé, grilse have been found in some years to exceed the adults in the ratio of 3 to 1. They run into the Nepissiguit mostly between July 25 and September 1. Their scarcity during the early part of the angling season, or say previous to July 20, is attested by numerous fishing scores. A series of scores of salmon fishing in the Godbout River, on the north side of the St. Lawrence, shows that previous to July 15 or 20 the adult salmon taken with the fly in that river exceed the grilse in the ratio of 10 to 1 or more.

In our rivers grilse are seldom seen, and only 3 or 4 are taken per year in a weir in the St. Croix, which takes about 70 adults. In the Dennys River the ratio of grilse to salmon caught is not more than 1 to 500, and in the Penobscot they are quite as rare. Adult salmon running in this river several weeks earlier than in those of eastern New Brunswick, we

* There has been considerable discussion on this point, and the conclusions of some observers are at variance with the above statement. In Scotland many years ago it seemed to be well established by the observations of Buist that a portion of the young salmon put on the silvery coat and went to sea at the age of one year, but that others of the same brood did not get ready to go until two years old. American observations, however, tend strongly to the conclusion that the young salmon passes two whole summers in the river, going out to sea in the autumn following its second summer or the next spring. It is not probable that the seaward migration is restricted in any river to any exact period of a few weeks duration, but that it extends over many months, some of the young salmon, by reason of superior native vigor of growth or from other equally efficient cause, attaining the migratory stage months earlier than others of the same brood.

It is the opinion of one American observer that salmon fry remain in the streams until October of the second year before going to sea, and that they do not go down until the spring of the third year; i. e., when they are two years old; though some may go down the fall of the second year; and that the salmon do not return until they are four years old.

should naturally expect the advent of grilse early in July in considerable numbers; but some of the weirs are often kept in operation until the middle or last of July, and sometimes even through August, when they take menhaden; but no grilse enter them. During the latter part of the summer the water at the several falls between Bangor and Oldtown is generally at a low stage, and the attempt of grilse, even in small numbers, to ascend the river could hardly fail to be frequently detected. A similar state of things exists in the Kennebec. There is no escaping the conclusion that the great run of grilse, which is so prominent a feature in the history of the salmon of northern rivers, is almost entirely wanting in the rivers of the United States. It by no means follows from this that our salmon do not pass through the same phases of growth, or that the growth is more rapid, but merely that when in the grilse stage they generally lack the instinct that impels their more northern relatives to seek fresh water.

Of the characteristics of grilse, as ascertained in the rivers they frequent, it will be sufficient to say that they exhibit to a great degree the characteristics of the adult; that the main external differences are a shorter head, slenderer form, and a difference in the color and markings; that they are remarkably active and agile, leaping to great heights; that the male is sexually well developed and mates with the adult, but that the female is immature, and that, like the adult, they abstain from food and consequently lose flesh during their stay in fresh water.

The next stage of life of the fish is that of the adult salmon, and this is the stage at which, with the exceptions indicated above, the Atlantic salmon first ascends the rivers of the United States. Assuming that it relinquished the rivers for the sea at the age of two years, being then a smolt, it has been absent two years, and it is now four years or a little more since it burst the shell. This estimate of age is based on the observations made by the Massachusetts commissioners of fisheries on the return of salmon to the Merrimac River, which plainly established the fact that the entire period between the hatching of the fry and the return of the adult to the rivers is about four years. Whether the same rule holds in other New England rivers can not as yet be established, owing to deficient data, but the presumption is in favor of that conclusion. In Canadian rivers the same period of growth appears to be the universal rule, at least as far north as the St. Lawrence River. Statistics of the catch of salmon for many years in eighteen separate districts, showing many fluctuations, exhibit a remarkable tendency of the figures to arrange themselves in periods of five years; thus, the year 1875 having been a year of small catch of salmon, it also appears in most of the districts that the next year of abnormally small catch was 1880. Now, the eggs laid in 1875 would hatch in 1876, and the young hatched at that time would be grown in 1880, requiring thus four years from hatching to maturity, just as on the Merrimac. It would seem no other interpretation can be put upon the statistics.

ENTRANCE TO DEAD BROOK INCLOSURE FOR SALMON.

DEAD BROOK INCLOSURE FOR ATLANTIC SALMON, SHOWING PENS.

EARLY SALMON-CULTURE ON THE PENOBSCOT RIVER.

The movement for the reestablishment of the fisheries for salmon, shad, and other anadromous species in American rivers originated in the action of the legislatures of New Hampshire and Massachusetts, having in view primarily the fisheries of the Merrimac and Connecticut rivers. The course of the Connecticut lies partly in the State of Connecticut, while many of its tributaries are in the State of Vermont, and these two States were therefore early interested in the project, and their action soon led to a similar movement on the part of Rhode Island and Maine. The rivers within the borders of these six States are the only ones in the United States known to have been frequented by the seagoing *Salmo salar*, except possibly the Hudson and certain rivers tributary to the St. Lawrence, in the northern part of New York.

The commissioners to whom the governments of the above States confided the task of restocking the exhausted rivers turned their attention at once to the two most important of the migratory fishes, the salmon and the shad. The utter extermination of salmon from most of the rivers compelling the commissioners to consider the best mode of introducing them from abroad, eggs were obtained for a time from the spawning-beds in the rivers of Canada and hatched with a measure of success. After a few seasons permits for such operations were discontinued, and it became essential to look elsewhere for a supply of salmon ova. In 1870 attention was directed to the Penobscot River, in the State of Maine, which, though very unproductive compared with Canadian rivers, might yet, perhaps, be made to yield the requisite quantity of spawn. The fisheries are all in the lower part of the river and in the estuary into which it empties, Penobscot Bay, and there the supply of adult salmon could be found with certainty, but they must be obtained from the ordinary salmon fisheries in June and held in durance until October or November, and the possibility of confining them without interfering seriously with the normal action of their reproductive functions was not yet established.

This plan was finally adopted, and in 1871 this method of breeding salmon was first attempted. For the purpose of the experiment, a point at the mouth of Craig Brook, which is by water nearly 9 miles distant from the mouth of the Penobscot River, more than half the route being through brackish water, was selected as the most convenient fresh-water stream which offered facilities for confining the salmon and maturing their eggs. After some unsuccessful trials means were found of safely conveying a few live salmon in floating cars from the fishing-grounds to the station, where they were held till the spawning season, when their eggs were taken and impregnated.

From 1872 to 1876 operations were conducted on a larger scale, with a fair degree of success, and, after a suspension, were resumed in 1879 at Craig Brook hatchery, while the retaining inclosures were located in Dead Brook, about 2 miles distant. The disadvantage of this

distance between the hatchery and retaining-ponds was offset by other advantageous conditions.

Until 1886 no attempt was made to rear salmon, and with unimportant exceptions the work was confined to the collection of salmon eggs, their development during the earlier stages, and their transfer in winter to other stations to be hatched. In 1889, however, the United States Fish Commissioner decided to establish a permanent station at Craig Brook, and in anticipation of the purchase of the premises, which was concluded the following year, the rearing of salmon to the age of six or seven months was undertaken as the leading work of the station.

WATER FOR A SALMON HATCHERY.

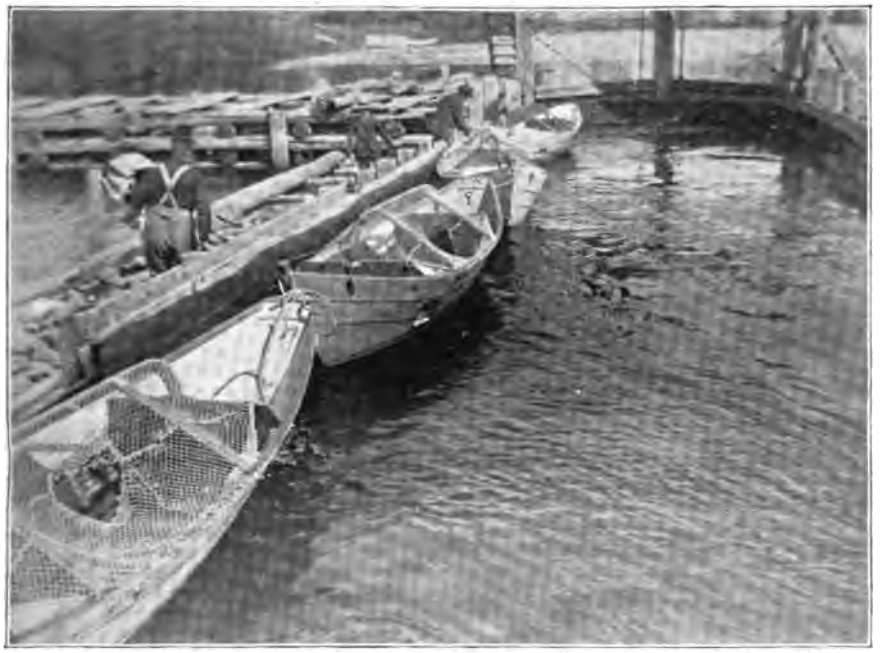
The first requisite for a salmon hatchery is an ample supply of suitable water, on a site where it can be brought completely under control and the requisite fall secured. In this matter there is quite a range of choice. The very best is the water from a stream fed by a clean lake of considerable depth, taken a short distance below the outlet of the lake, with an intervening rapid. Craig Pond may be taken as an example of such a lake. It has an area of 231 acres, an extreme depth of 69 feet, and a depth of 25 feet within 500 feet of the outlet. The depth directly influences the temperature and, other things being equal, a deep lake will afford water more uniform in temperature than a shallow one—cooler in summer and warmer, though never too warm, in winter. Such water is commonly quite even in volume and temperature, and comparatively pure. It is cold in winter and warms up slowly in spring, assuring a slow, normal development of the eggs, which is more conducive to health and vigor than a quicker development. The passage down a rapid will further improve this water by charging it highly with air.

After this, the water of a brook is to be chosen that is fed largely by springs, so as to insure constancy in the supply and some moderation of the temperature on warm days, but it is better to have the water flow a long distance in an open channel before using, and, if possible, over a rough and descending bed, that it may be well aerated, and in cold weather somewhat cooled down from the temperature with which it springs from the ground.

The next best is pure spring water; but in all cases where this is used a cooling and aerating pond is necessary, that the original warmth of the water may be subdued by the cold of the air before it reaches the hatching-troughs, and that it may absorb more or less air by its wide surface.

Lastly, choose ordinary river or brook water, as clean as possible. These are inferior to spring water by reason of liability to floods, drought, muddiness, and foulness of other sorts, and in cold climates to anchor ice.

Between these different sorts there is of course an infinite number of gradations. If lake water can not be obtained it would be of some



SALMON LIVE-CAR USED IN TRANSPORTING FISH FROM WEIRS TO DEAD BROOK.

SALMON LIVE-CARS EN ROUTE WITH FISH.

advantage to have a supply of both spring water and brook water, depending for ordinary use on the brook water or a mixture of the two, and on the spring water for emergencies, such as the freezing, drying, or excessive heating of the brook, floods with accompanying muddiness, etc. Water coming from boggy and stagnant ponds and marshes is objectionable; for though excellent water, capable of bringing out the most vigorous of fish, may sometimes be had in such places, yet when not supplied by springs it is dependent for its freshness and good qualities on rainfalls, and if these fail, as they are liable to, the water may become foul and unfit. It must be borne in mind that these remarks about the selection of water for fish-cultural purposes apply only to the culture of Atlantic or landlocked salmon, in a climate like that of the State of Maine.

It is best to select a site for a hatching establishment in time of extreme drought, and if it then has an ample supply of pure, sweet water the first requisites are fulfilled. It is well also to visit the place in time of flood and, if in a cold climate, in severe winter weather, to learn the dangers to be guarded against on those scores. The volume of water necessary will depend mainly on the proposed capacity of the establishment, the temperature of the water, its character as to aeration, and the facilities existing for the aeration and repeated use of the water. With water of the highest quality and low temperature, and with unlimited facilities for aeration, possibly a gallon a minute, or even less, can be made to answer for the incubation of 100,000 eggs of salmon. As the temperature rises or the facilities for aeration are curtailed a larger volume becomes necessary. In case of spring water, cooled only to 40° and aerated only by exposure to air in a pool of about a square rod surface, with no facilities in the house for aeration, and with the eggs and fry crowded in the troughs at the rate of 4,000 per square foot, 4 gallons a minute is the least that can be allowed, while 6, 8, or 10 gallons per minute are better. While the minimum is, as stated above, possibly less than a gallon a minute, it is not advisable to trust to less than 3 gallons per minute for each 100,000 eggs under the most favorable circumstances.

If the water supply is drawn from a small brook or spring, it is necessary to measure the volume approximately, which is easily done, in the following manner: With a wide board 1 inch thick, having a smooth inch hole bored through the middle, a tight dam is made across the stream so that all the water will have to flow through the hole. If the water on the upper side rises just to the top of the hole, it indicates a volume of 2.3 gallons per minute; a rise of half an inch above the top of the hole indicates a volume of 3.5 gallons per minute; 2 inches rise, 5 gallons per minute; 3 inches, 6 gallons per minute; 6 inches, 8 gallons per minute; 13 inches, 12 gallons per minute. If two 1-inch holes are bored, the same will, of course, indicate twice the volume. The volume of water flowing through holes of different sizes is in proportion to the

squares of their diameters; thus a 2-inch hole permits the passage of four times as much as a 1-inch hole. A tube whose length is three times its diameter will allow 29 per cent more water to pass than a hole of the same diameter through a thin plate or board.

SITE.

After a satisfactory supply of water is found a site for the hatching-house must be selected that affords facilities for creating a head of water to provide for the requisite fall into and through the troughs, security against inundation, security against too much freezing if in a cold climate, and, finally, general safety and accessibility. The fall required in the hatching-house can hardly be too great. The minimum is as low as 3 inches, but only under the most favorable circumstances in other respects will this answer, and even then it is only admissible where there is an ample supply of aerated water and the troughs are very short and there is absolutely no danger of inundation; and this fall has the disadvantages of the impracticability of introducing any aerating apparatus and the necessity of having the troughs sunk below the floor of the hatching-house, which makes the work of attending the eggs and fish very laborious.

A fall of 1 foot will do fairly well if there is entire safety from inundation, as this will permit the troughs being placed on the floor, which is a better position than below it, though still an inconvenient one, and some of the simpler aerating devices can be introduced. Better is a fall of 3 feet, and far better a fall of 6 feet. The latter permits the placing of the lowest hatching-troughs 2 feet above the floor and leaves ample room for complete aeration. The necessities of the case are dependent largely upon the volume and character of the water, and if there is plenty of it, well aerated before reaching the hatching-house, there is no occasion, in a small establishment, of additional aeration in the house, and therefore no need of more than 3 feet fall.

Inspection of the premises at time of floods will suggest the safeguards necessary to provide against inundation. If located by a brook-side, the hatching-house should not obtrude too much on the channel, and below the house there should be an ample outlet for everything that may come. By clearing out and enlarging a natural watercourse much can often be done to improve an originally bad site.

In a cold climate it is an excellent plan to have the hatching-house partly under ground, for greater protection against outside cold. When spring water is used there is rarely any trouble, even in a cool house, from the formation of ice in the troughs; but water from lake, river, or brook is, in the latitude of the northern tier of States, so cold in winter that if the air of the hatching-house is allowed to remain much below the freezing-point ice will form in the troughs and on the floor to such an extent as to be a serious annoyance, and if not watched will form in the hatching-troughs so deeply as to freeze the eggs and destroy

them. Stoves are needed in such climates to warm the air enough for the comfort of the attendants; but the house should be so located and constructed that it may be left without a fire for weeks without any dangerous accumulation of ice, and if the site does not permit of building the house partly under ground the walls must be thoroughly constructed and banked well with earth, sawdust, or other material. In warmer climates no trouble will be experienced from this source.

DAMS AND CONDUITS.

The requisite head of water can often be had by throwing a dam across the stream and locating the hatching-house close to it. The dam will form a small pond which will serve the triple purpose of cooling, aerating, and cleansing the water. But unless the bed and the banks of the stream are of such character as to preclude any danger of undermining or washing out the ends of the dam, it is best not to undertake to raise a great head in this way. With any bottom except one of solid ledge there is always great danger, and to guard against it when the dam is more than 2 feet high may be very troublesome. If there is a scarcity of water, or if it is desirable, for aerating or other purposes, to secure a considerable fall, it is better to construct the dam at some distance above the hatching-house, on higher ground, where a very low dam will suffice to turn the water into a conduit which will lead it into the hatching-house at the desired height.

A square conduit made of boards or planks, carefully jointed and nailed, is in nearly all cases perfectly satisfactory, and for an ordinary establishment a very small one will suffice.

The volume of water that will flow through a pipe of a given form depends upon its size and the inclination at which it is laid. A straight cylindrical pipe, 1 inch in diameter, inclined 1 foot in 10, conveys about 11 gallons of water per minute. The same pipe, with an inclination of 1 in 20, conveys 8 gallons per minute; with an inclination of 1 in 100, it conveys 3½ gallons per minute; with an inclination of 1 in 1,000, it conveys 1 gallon per minute. A 2-inch pipe conveys about 5½ times as much water as an inch pipe; a 3-inch pipe nearly 15 times as much. A 1-inch pipe, with an inclination of 1 in 1,000, conveys water enough for hatching 25,000 eggs; with an inclination of 1 in 50, enough for 100,000 eggs; with an inclination of 1 in 20, enough for nearly 200,000 eggs. A square conduit conveys one-quarter more water than a cylindrical pipe of the same diameter. If there are any angles or abrupt bends in the pipe, its capacity will be considerably reduced. It should be remembered that if the water completely fills the aqueduct it is entirely shut out from contact with the air during its passage, whereas if the pipe is larger than the water can fill, the remainder of the space will be occupied by air, of which the water, rushing down the incline, will absorb a considerable volume and be greatly improved. It is therefore much better to make the conduit twice or thrice the size

demanded by the required volume of water. If the bottom and sides are rough, so as to break up the water, so much the better, and the wider the conduit is the more surface does the water present to the air.

AERATION.

The water which fishes breathe is but the medium for the conveyance of air, which is the real vivifying agent, without which fish and eggs will die, and with a scanty supply of which the proper development of the growing embryo is impossible. Water readily absorbs air whenever it comes in contact with it, and the more intimate and the longer continued the contact the greater the volume it will absorb. The ample aeration of the water to be used in the hatching-house has already been mentioned as a desideratum of the first importance, and some of the devices by which it is to be secured have been alluded to.

Water from either a brook or a river that has been torn into froth by dashing down a steep bed has absorbed all the air that is needed in 10 or 20 feet of hatching-trough, and demands no further attention on this score; but if the water is taken from a lake, a spring, or a quiet brook it contains less air, which may be so reduced before it gets through the hatching-house as to be unable to do its proper work. It is therefore desirable to adopt all practicable means of reinforcing it. If the site of the hatching-house commands a fall of 5 feet or more, the object may be attained by contriving in the conduit outside the house, or in the hatching-troughs themselves, a series of miniature cascades.

The broader and thinner the sheet of water the more thoroughly it is exposed to the air, and if, instead of being allowed to trickle down the face of a perpendicular board, it is carried off so that it must fall free through the air, both surfaces of the sheet are exposed and the effect is doubled. When circumstances permit, it is best to aerate in the conduit, which, as already suggested, may be made wide and open for that purpose.

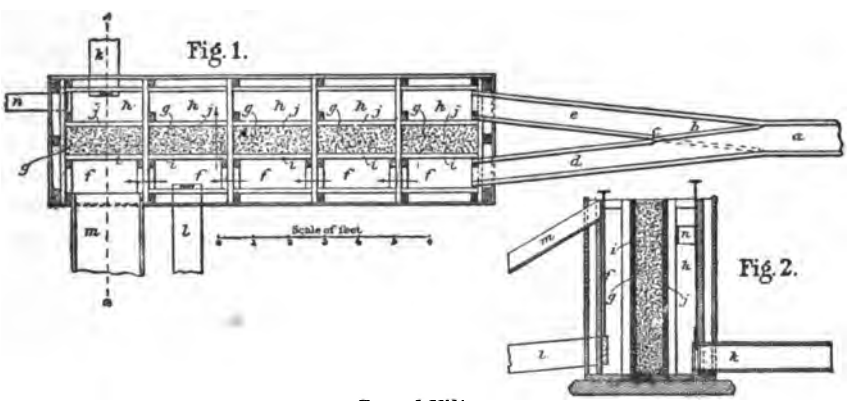
If aeration can not be effected outside the house it may be done inside by arranging two long troughs side by side, leveled carefully, so that the water is received in one of them and poured over into the other in a sheet the whole length of the trough. In the hatching-troughs themselves there is an opportunity for aeration, either by making short troughs with a fall from one to another or by inclining the troughs and creating falls at regular distances by partitions or dams, each with its cascade, after the fashion already described. The only serious difficulty is encountered where the ground is very flat, so that the requisite fall can not be obtained, and in this case the best that can be done is to make a very large pool, several square rods at least, outside the house, and make all the conduits as wide as possible, so that the water shall flow in a wide and shallow stream.

It will of course be borne in mind that the better the aeration the smaller the volume required to do a given work, and on the other hand

it is equally true that the greater the volume the less aeration is necessary. When so large a volume as 6 gallons per minute for every 100,000 eggs is at command, a comparatively small amount of aeration will answer. But, so far as known, the higher the degree of aeration the better the result, without limit, other things being equal, and it is therefore advised to make use of all the facilities existing for this purpose.

FILTERING.

Before the introduction of wire or glass trays for hatching fish eggs it was customary to lay them on gravel, and it was then absolutely necessary to filter all but the purest water. Even ordinary spring water deposits a very considerable sediment, which might accumulate upon the eggs to such an extent as to deprive them of a change of



Gravel Filter.

a, conduit from brook.
b, gate, swinging on pivot at *c*, to change direction of water.
d, direct branch of conduit.
e, reverse branch of conduit.
f, *f*, *etc.*, a single long compartment for unfiltered water.
g, *g*, *etc.*, compartments occupied by gravel.
h, a single long compartment for filtered water.
i, *j*, racks to hold gravel in place.
i is in 5 sections, movable, and can be taken out when gravel is to be renewed.
k, *l*, sluices near bottom for cleaning out.
m, wasteway.
n, aqueduct to hatchery.

water and smother and destroy them. When, however, eggs are deposited on trays arranged for a circulation of water beneath, as well as over them, as described below, even though their upper sides are covered with sediment, they are clean and bright underneath and remain in communication with the water beneath the tray, though of course the circulation of the water through the tray is not perfect. It is not, therefore, deemed necessary to introduce any considerable devices for filtering water which is naturally very pure, like lake and spring water when not subject to intermixture with surface water during rains; but where it is necessary to use water subject to constant or occasional turbidness some method of filtering is indispensable.

In the majority of cases at least a portion of the water supply is obtained from an open brook, lake, or pond, and measures must be taken

to get rid of the leaves and other coarse rubbish brought down by the stream or conduit. A great deal of such material is encountered in a stream at all seasons of the year, but during the fall and early winter it is especially abundant, and to secure entire safety from a stoppage of the water, and consequent loss, a screen on a generous scale must be provided.

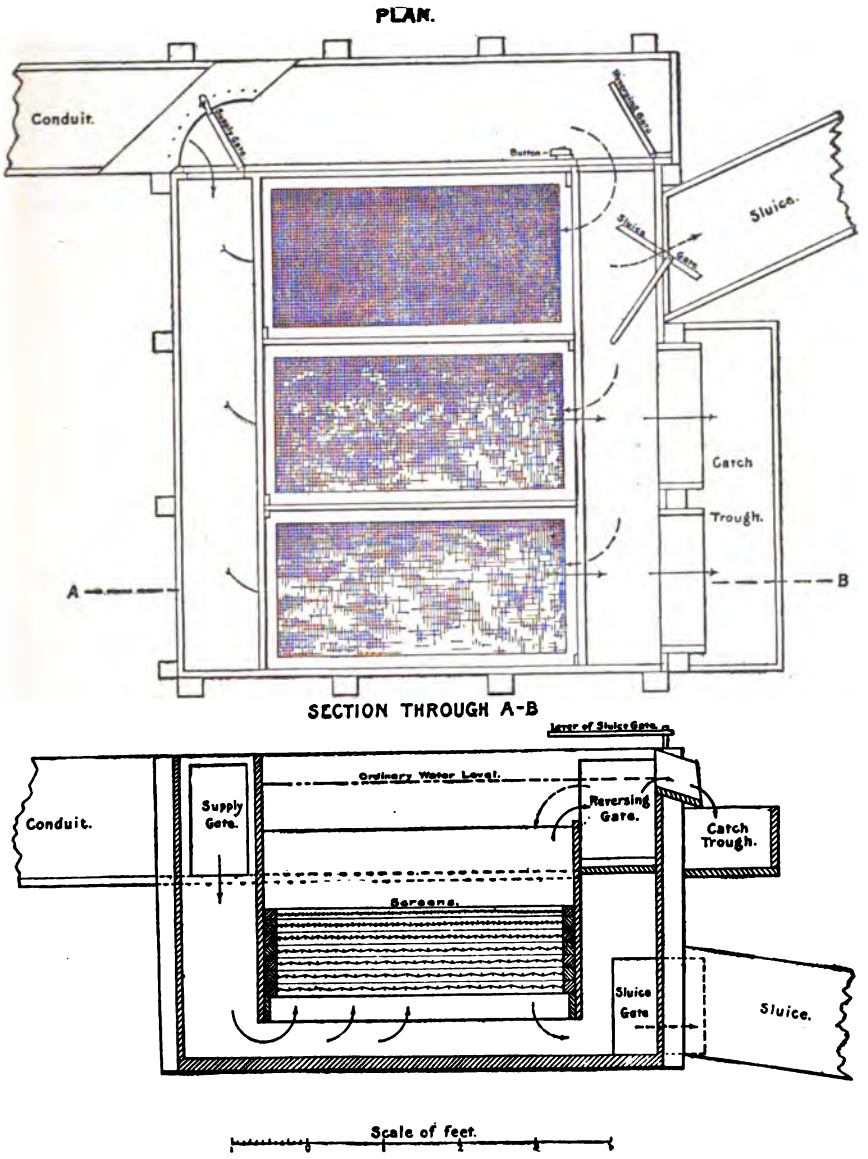
A description of the means adopted at this station for providing a temporary extra water service of several hundred gallons per minute, taken from Craig Brook, will serve as an illustration: A tank or vat, 12 feet square and about 2 feet deep, is built in the bed of the brook with a tight dam of stones, gravel, loam, and leaves (these to stop small leaks) running ashore on either side, so that the entire volume of the brook passes over the tank. The bottom and sides are tight and strong, and both bottom and top are inclined about 6 inches down the stream. The cover is of spruce lumber sawed 1½ inches square and nailed on in the direction of the current, with interstices open half an inch; when in operation the water fills the tank and runs over the lower edge, which is raised enough to maintain a depth of several inches over nearly the whole tank. All leaves and other materials floating near the surface of the water are carried over, together with most rubbish which floats deep. At one of the lower corners of the tank, near the bottom, is a gate about 15 inches square, which is hung by hinges on its upper side. It opens inward, and is closed tightly by the pressure of the water; but it can be easily opened by pushing with a pole from without, and then serves as a floodgate, whereby the tank may be thoroughly cleaned out.

At the other lower corner is a conduit, 6 by 9 inches, which takes from this "leaf-screen" a supply of water not entirely free from rubbish, but so nearly so that a filter of moderate capacity can cope with what remains. A very useful adjunct would be a second horizontal screen of similar construction, through which the water that has passed downward through the first screen, as described, should next pass upward through the second; the first screen would remove floating débris, the second such as is heavier than water.

The filter, situated about 70 feet from the leaf-screen, consists of a wooden flume, 12 feet long and 4 feet deep, divided lengthwise into three compartments, of which the central contains fine gravel held in place by a rack on either hand, of which the interstices are ½ inch wide and 1½ inches apart. The water from the leaf-screen is introduced into one of the lateral compartments, and filters through the gravel into the opposite compartment, from which it is taken by a plank aqueduct, 6 by 6 inches, to the hatchery. Under the conditions described, and with a fall of about 1 foot from supply to discharge, this filter discharges over 300 gallons of water per minute into the aqueduct—water not absolutely pure, but sufficiently free from coarse dirt for the purpose.

In many cases, where small quantities of water are used, it is custo-

mary to filter through flannel screens in the hatchery, and such filters do very good service. They can be introduced into the egg-troughs, or by running them lengthwise of a trough a very large volume of water can be filtered.



Wire Filter.

A form of filter that has given good satisfaction at the Craig Brook station through five years of service consists of a series of graduated wire screens, through which the water passes upward, first through the coarser and then through the finer screens, with provision for the

reversal of the current for cleaning purposes. By reference to the cut on page 29, it will be seen that the water is brought to the filter through a plank conduit, and is admitted to the filter through either of two gates that swing on hinges, one for the direct flow and the other for the reversal. The direct flow is first into a receiving chamber, which extends under the screens, then upward through the whole series and out at the top, overflowing into a catch-trough, from which it is distributed as desired. In cleansing, the supply-gate is closed and the other one opened, and at the same time the sluice-gate at the bottom is opened; the water then flows in full volume upon the screens and down through them, carrying all the intercepted débris into the lower chamber and out through the sluice-gate.

The wire filter illustrated has to pass some 500 gallons of water per minute, and has three screen-boxes, each of which carries 5 to 7 screens about 2 feet wide and 4 feet long; the meshes are from 2 inches down to ⅛ inch square, and therefore intercept all coarse débris.

It is but the work of a few moments to reverse the current and thoroughly cleanse the screens; when the autumn leaves are falling this must be done several times a day, but at other seasons some days elapse between the cleanings. The wire—even galvanized—rusts out in two or three years, and lately the coarser screens have been made of slender rods of oak, which will undoubtedly prove more durable.

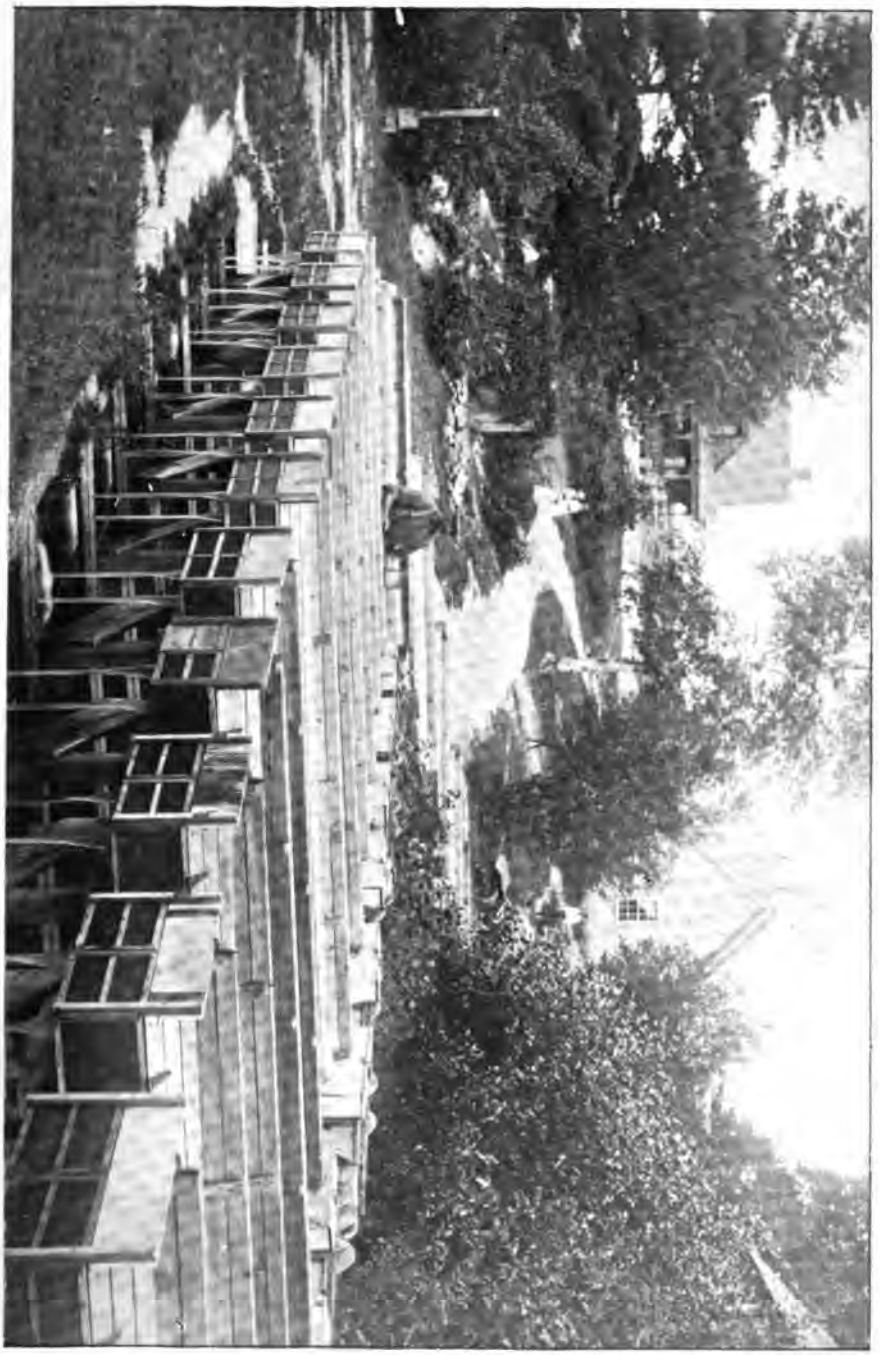
None of the filters described will intercept the finest sediment, and the water is finally passed through a capacious wooden reservoir, 30 feet long, 8 feet wide, and 5½ feet deep, before it reaches the troughs. This answers the purpose well for the amount of water supplied by the filter last described (about 500 gallons per minute) and is regarded as well worth having, though even this will not insure limpidity in the water when the brook is swollen by rains.

It may be mentioned that this reservoir is kept brimful at all times, so that all portions of the woodwork, except the railing surrounding it, are kept continuously wet and thus insured against decay for a very long period of years.

CRAIG BROOK HATCHERY AND ITS EQUIPMENT.

The Craig Brook hatchery derives its water supply from the brook, which has its source in Craig Pond, but which receives in the lower part of its course many copious springs. This spring water has some advantages, but possesses the serious disadvantage of such high temperature in winter as to unduly hasten the development of the eggs, causing them to hatch early and necessitating shipments of eggs in December.

Accordingly, an aqueduct from a point on the brook above the springs brings to the hatchery a supply of cold water for winter use, in which eggs taken the first of November will not hatch until the following April. This is important, as, if the product of the season's hatching is to be liberated as fry, the late date of hatching will bring them to the feeding stage about the time when suitable food abounds in



SALMON REARING-TROUGHS, WITH RESIDENCE AND BARRACKS IN BACKGROUND, CRAIG BROOK STATION, MAINE.

open waters, and if they are to be reared it is well to shorten up the sac-stage and to have the early feeding-stage fall at a date when the temperature of the water is rapidly rising, which will get the fish quickly through that most difficult of all stages of growth.

The aqueduct is about 1,600 feet long, with a bore 4½ inches, and has a nearly uniform descent and total freedom from depressions, and is from end to end one single piece of cement concrete. It delivers to the hatchery about 100 gallons of water per minute, which is sufficient for the development of 4,000,000 eggs, and possibly many more. It was built in place around a slightly tapering core, which was drawn forward as fast as the mortar set, and it has now done good service for seventeen years. By this means the temperature of the hatchery water is maintained 3° below that of the brook modified by the springs. During the five months from November 1, 1895, to April 1, 1896, the mean temperature in the hatchery was 36.65° F.

COLLECTION OF STOCK SALMON.

The only salmon fisheries available for the purpose of supplying Craig Brook station with breeding fish are those carried on by weirs about the mouth of the Penobscot. Arrangements are made early in the season with weir fishermen to save their salmon alive and deliver them daily to the collecting agent of the station, who makes the rounds of the district about low water with a small steamer, which tows the cars containing the fish on the flood-tide to Orland village, where they are passed through the lock about high water and taken by a crew of oarsmen to the inclosure at Dead Brook.

In anticipation of this work, the fisherman places the floor of his weir a little lower than he would otherwise do, so that at low water the salmon may have water to swim in instead of being left high and dry by the retreating tide, in case of an accidental delay or failure to visit the weir at the usual hour. It is, however, the ordinary practice to take the salmon out at each "fish-tide," i. e., low water, and place them in a car. Cars enough are stationed among the fishermen to bring one at least in each neighborhood, and in most cases the car is brought alongside and the salmon transferred to it directly from the weir, though in some cases it is necessary to place the salmon first in a box, in which it is carried by a boat to the car. The car employed is made from the common dory, divided transversely into three compartments. The central one, which is much the larger, is occupied by the fish, and is smoothly lined with thin boards and covered with a net to prevent the fish jumping out or being lost by the car capsizing, which sometimes occurs, while to guard them from fright and the rays of the sun a canvas cover is drawn over all.

The first cars of this form had iron gratings to separate the central from the forward and after compartments, the water being admitted through the forward and discharged through the after compartment, but this was objectionable because the salmon were constantly seeking

to escape through the forward grating, and often injured themselves by rushing against it. Smooth wooden gratings were afterwards used and for many years cars were employed in which the compartments were separated by tight board partitions, the openings for the circulation of water communicating through the sides of the boat directly with the fish compartment and being, of course, grated. This was a very satisfactory form, but when it was found desirable and practicable to use ice in transportation, the forward compartment became the ice-room, and it was necessary to perforate the partition again to admit the cold water to the fish. Finally, stout woolen blanket cloth was substituted in the partitions, with eyelet holes to afford passage to the water. This is the form now in use, in which the water is admitted through openings in the sides to the ice-room, from which it passes through the fish-room to the after room, whence it is discharged.

The car is ballasted so that the rail is just above water or, in case of an unusually large load of fish, a little below it. All the openings communicating with the outside are controlled by slides, which can be closed so as to let the car swim high and light when it is towed empty.

The boxes used for the transfer of salmon hold about 90 gallons each, and are 2 feet wide, 2 feet deep, and 3 feet long, with a sliding cover, in the center of which is an inch auger-hole for ventilation. Such boxes were used at Bucksport from 1872 to 1874 to convey the salmon on drays from the cars to the inclosure, a distance of a little over a mile; six or eight salmon were taken at once, the box being filled brimful of water, which was brackish and generally clear and cool. Though the largest fish could not lie straight in the box, and the time occupied in transit was commonly twenty minutes, they as a rule arrived at the pond in good condition.

To avoid injury to the fish in transferring them to the cars, fine dip nets, lined with woolen flannel of open texture, are used. The bow on which the net is hung is 22 inches in diameter, and to secure a net of ample width three ordinary nets, 36 inches in depth, are cut open down one side quite to the bottom, and then sewed together, giving thus three times the ordinary breadth without increasing the depth.

The collection of salmon is begun each season usually from the 20th of May to the 1st of June, but as the maximum temperature that the fish fresh from the weirs will endure is about 75° F., the temperature of the water through which the cars are towed must be taken into consideration, and the collection not be postponed until too late in the season. If the collection is prolonged, this difficulty is obviated by using ice, as it has been found that by moderating the volume of water passing through the car and introducing it all through the ice compartment it is possible to keep a uniform temperature in the compartment in which the fish are held several degrees below that of the water in the river, thereby insuring the safe transfer of the salmon.

The principal sources of Dead Brook are two small lakes, and on some of the tributaries there are considerable springs. While the

water is slightly purer than that of ordinary brooks, it is by no means so transparent as that of Craig Brook, and the bottom can hardly be be seen at the depth of 4 feet. This circumstance is regarded as favorable. The inclosure is located on the lower stretches of the brook, not more than half a mile from its mouth, with low banks on either hand and a very gentle current flowing over a bed that is for the most part gravelly but in part consists of a peaty mud that supports a luxurious growth of aquatic vegetation. The general depth is less than 4 feet, but two of the pools are 8 feet deep and another is 6 feet deep. The width of the stream is from 20 to 80 feet. The inclosure occupies the entire stream for a distance of 2,200 feet, embracing an area of about 2½ acres. At either end is a substantial barrier, consisting of wooden racks, which obstruct the current very slightly but confine the salmon securely. The lower barrier is provided with a gate, which swings open to admit boats, and at the upper barrier are the spawning-house and watchman's camp and a small storehouse.

The temperature of the water during the summer months generally ranges between 60° and 70° F., but the surface temperature occasionally rises to 76°, 80°, and even 84°. During sultry weather the temperature at the bottom has been observed and in the deeper pools has been found to be notably lower than at the surface. Thus a temperature of 75° at the surface has been found to be accompanied by 68° at the bottom; 78° by 74°; and 81° by 72°. It is probable that to the existence of these deeper pools the survival of the salmon through extremely hot weather may be ascribed.

After their liberation in the inclosure the salmon are at first quite active, swimming about and often leaping into the air. This continues for several weeks, after which they become very quiet, lying in the deepest pools and rarely showing themselves until the approach of the spawning season.

Most of the deaths occur during the first few weeks of their imprisonment, doubtless in consequence of injuries received in capture or during transfer, though high temperature in the inclosure itself about the time of the introduction of the salmon may be one of the causes of mortality. Fish that escape the dangers of June appear to become acclimated and able to endure the high temperatures of July and August without injury.

Notwithstanding salmon enter the rivers in spring or early summer, ascending at once to their upper waters and there, in fresh water, awaiting the spawning season, fresh water is not essential to the activity of their reproductive functions. At the Canadian fish-breeding station of Tadoussac, where salmon are almost the only fish cultivated, it has for many years been the practice to hold their brood fish in an inclosure supplied with salt water, which flows and ebbs through the barrier confining the salmon, and the development of eggs and milt is in no wise unfavorably affected.

THE EGG HARVEST.

The natural deposit of spawn by the Atlantic salmon in the rivers of the United States occurs during the months of October and November. In artificial operations at Dead Brook it has rarely been necessary to begin spawning before October 22, or to close later than November 15.*

Dead Brook is commonly at a very low stage in August and September, but it rarely fails that before October 20 there is a very material increase in volume. Whenever a sudden rise occurs, even in August or September, imprisoned salmon are at once excited to activity, and any aperture in the upper barrier sufficient to admit the body of a salmon is sure to lead to loss. As the breeding season approaches the sensitiveness of the fish to such influences increases, and a rise about October 20 is followed by a general movement of the salmon upstream in search of spawning-grounds. Advantage is taken of this circumstance to entrap them at the upper barrier, where a small pound with a board floor and a barbed entrance, like that of a weir, is constructed a few days in advance. The success of this trap depends on the stage of the water, and it is always the case that a portion of the fish fail to enter it, so that the final resort is to a seine, with which the recalcitrant salmon are swept out of pools where they are wont to lie.

The fish are dipped from the trap or from the seine with soft bag-nets, such as are used in collecting them at the beginning of the season, assorted according to sex and condition, to facilitate manipulation, and placed in floating wooden pens, which are moored to the bank in front of the spawn-house. These pens are about 12 feet long and 4 feet wide, with grated sides and floors, affording sufficient circulation of water, and, although indispensable for the convenient manipulation of the fish, the confinement in such narrow quarters leads to considerable chafing of noses and tails, and if long continued affects the development of the sexual functions of the female unfavorably, retarding the maturity of the eggs and even affecting their quality. The capture of the fish from the brook is therefore delayed to the point of risking the deposit of some of the earliest eggs in the brook rather than the possible injuries in the pens.

The spawn-taking operations begin as soon as any females are ready to yield their eggs. A scarcity of males in breeding condition has never yet occurred at this station at the beginning of the season, and hardly ever at its close. Among the earliest captures there are always a few unripe fish, but invariably by the last day of October all are ripe.

The spawning-house consists of a single, plain room, with two doors. From one of the beams hangs a steelyard and a bag, in which salmon are weighed. At one end is a stove, in which a fire is built in very cold weather. At the other end is a graduated board, upon which the

* In Canadian rivers the dates are but a little earlier. Thus at the Gaspé hatchery, in the Province of Quebec, in 1894, the work of spawning began October 10 and closed November 2.

Ripe female salmon.

Male salmon.

EXAMINING FISH FOR STRIPPING.

STRIPPING FEMALE SALMON.

fish are laid for measurement. At the front is a narrow table, on which the eggs are washed; and at the rear the entire side of the room is occupied by a series of shelves, on which the eggs are placed after fecundation and washing.

The spawn-taker, clad in waterproof clothing and wearing woolen mittens, sits on a stool or box, and on a box in front of him is a clean tin pan holding about 10 quarts, which has been rinsed and emptied but not wiped out. A female salmon is dipped up from one of the floating pens and brought to the operator, who seizes her by the tail with the right hand and holds her up, head downward. If unripe, the fish is returned to the pens; if ripe, the spawn will be loose and soft and will run down toward the head, leaving the region of the vent loose and flabby, and the operator, retaining his hold of the tail with his right hand, places the head of the fish under his left arm with the back uppermost, the head highest, and the vent immediately over the pan. At first the fish generally struggles violently and no spawn will flow; but as soon as she yields the eggs flow in a continuous stream, rattling sometimes with great force against the bottom of the pan. Shortly the flow slackens and must be encouraged and forced by pressing and stroking the abdomen with the left hand. It is better to use the face of the palm or the edge of the hand rather than pinch between the thumb and finger; the latter action, especially when working down near the vent, is apt to rupture some of the minor blood vessels, with the result of internal bleeding, and it is better to leave some of the eggs behind to be taken another day than to run the risk of such ruptures.

If the fish in hand is fully ripe, nine-tenths of the eggs are obtained at the first trial. When the operation has apparently gone far enough for the first day, the fish is laid in the weighing bag, and as soon as the weight is recorded is stretched upon the measuring board, whence she is returned to the water, after a stay of 10 or 15 minutes in the air, which results in no permanent injury. Both the weight and length of the fish and the weight of the eggs are recorded, together with anything remarkable connected with fish or eggs.

Large salmon endure transportation and confinement less successfully than smaller ones, and the record therefore shows large numbers of salmon from 29 to 31 inches in length, weighing, including eggs, from 9 to 12 pounds, and yielding 2½ to 3 pounds of spawn (6,000 to 8,700 eggs), with now and then a fish 35 or 40 inches in length, yielding, in some cases, as many as 16,000 to 20,000 eggs.

As soon as the spawn of a single female is taken, a male is brought to the spawn-taker and the milt expressed upon the eggs. The pan is then swayed and shaken violently until the milt becomes well distributed and in contact with every egg. If the quantity of spawn exceeds 3 pounds it is divided and fecundated in two pans instead of one, as it is difficult to secure a good result if the eggs lie in too great

masses. The eggs are passed over to the washer, who repeats the swaying and the shaking, and, having weighed them, pours in a small quantity of water and goes through the mixing process for a third time. After this the eggs are immediately washed by pouring in an abundance of water and turning it off, and repeating the operation until the water appears quite clear, when the eggs are placed on the shelves in the rear of the apartment, to await the process of swelling. When the egg first comes from the fish it has a soft and velvety feeling to the hand, and the outer shell lies loose and slack against the yolk. The presence of water excites the shell to action; its pores absorb water with such force that any foreign object coming in contact is sucked against it, and in consequence of this suction the eggs stick to the pan and to each other. In the course of 20 or 30 minutes this process is completed, the shell is swollen to its utmost extent and is firm to the touch, the space between the shell and the yolk is now filled with water, and adhesion to outer objects ceases.

The eggs can now be laid upon trays and carried to the hatchery. No serious harm would ensue if the eggs should be disturbed during the process of swelling, but it is better not to spread them upon trays until they have attained full size and ceased to adhere to each other, and they are left on the shelves until the spawning for the day is over, when all are carried to the hatchery together. After the absorption of water the eggs must be handled very gently, as they are now susceptible to injury from sudden shocks, such as might ensue from pouring them from pan to pan, or setting the pan containing them down roughly upon a wooden table, and to guard against such injuries the tables and shelves are covered with old nets or other soft material.

CONDITIONS AFFECTING FECUNDATION OF EGGS.

While the spawn of a salmon is, with very rare exceptions, in normal and healthy condition and capable of fecundation within the limits of the spawning season, occasionally a fish is found whose eggs are in some way defective. Sometimes they are developed unevenly, the ovaries containing eggs in various stages of growth, some mature and some rudimentary; sometimes all the eggs of a fish are abnormally small, and sometimes all have defects which render them incapable of fecundation. But among the thousands that have been manipulated at the station not 1 in 300 has had defects involving as many as 20 per cent of her eggs, and in the spawn deemed of normal quality there can hardly be more than 1 defective egg in 400. Among the males no instance has occurred where there was reason to suspect the milt of being of defective quality if secured from a living fish.

In 1872 experiments were made bearing on the duration of the capacity for fecundation of the eggs with interesting results. From eight lots of eggs taken from dead fish, the rates of impregnation ranged from 92½ per cent down to zero. From a fish that had been dead 2

hours 4,400 eggs were obtained, of which only 58½ per cent were capable of fecundation. In one instance eggs taken from a dead fish and kept until the morrow before milting remained so far in normal condition that 12½ per cent were fecundated. In another case 400 eggs from a fish that had been dead 15 hours failed totally; and the same result was obtained with 2,200 eggs taken from four specimens killed two days before.

The same experiments afford evidence as to the result of keeping eggs for various periods of time after they are taken from the fish, and eggs exposed to the air and guarded against contact with water appear to keep better than in the organs of a dead fish. Thus, 200 eggs were kept in a pan without water for 12 hours after they were taken from the fish, and the application of milt then resulted in the impregnation of 90 per cent; of 200 eggs kept in the same way for 30 hours and then treated with fresh milt, 87½ per cent were impregnated; and of 100 eggs kept 4 days and then treated with fresh milt, 12 were impregnated.

Milt taken from a living male and kept in an open dish for several hours retains its powers fully, but experiments with milt from dead fish have given almost wholly negative results. Numerous experiments show that if eggs are merely covered by water, without effort to secure intermixture or the washing off of the mucus that envelops them when pressed from the organs of the mother fish, their susceptibility to fecundation may not be seriously affected by immersion 5 or 6 minutes; but if the eggs are stirred, so as to facilitate the washing off of the mucus and the access of pure water, immersion for 1 or 2 minutes may prevent impregnation.

When thoroughly diluted with water the milt speedily loses its power, the effect being very marked at the end of 30 seconds; diluted with the mucus that accompanies the egg, it will remain effective for a long period. Where water has been carefully excluded, milt has been used successfully after the lapse of 12 hours with landlocked salmon, and this would probably hold with eggs of all kinds of salmon and trout. This property of the mixed mucus and milt has been utilized in impregnating masses of eggs when there is a scarcity of males, as sometimes occurs toward the close of the spawning season. In straining the mixed mucus and milt from the pan of eggs, the lower strata, which are richer in milt than the upper, should be especially secured and the mixture kept in a convenient receptacle. The upper strata of the mixture should not be used, as the milt settles to the bottom. Fresh milt should always be preferred when obtainable.

The eggs are washed as soon as the milt is thoroughly diffused among them, and this can hardly be done too speedily for the milt to act. A careful record of certain lots of eggs that were washed in special haste for experimental purposes shows that they were as well impregnated as those exposed to the action of the milt for a considerable period. Prolonged exposure to the milt has been found to affect the health and development of the embryo unfavorably.

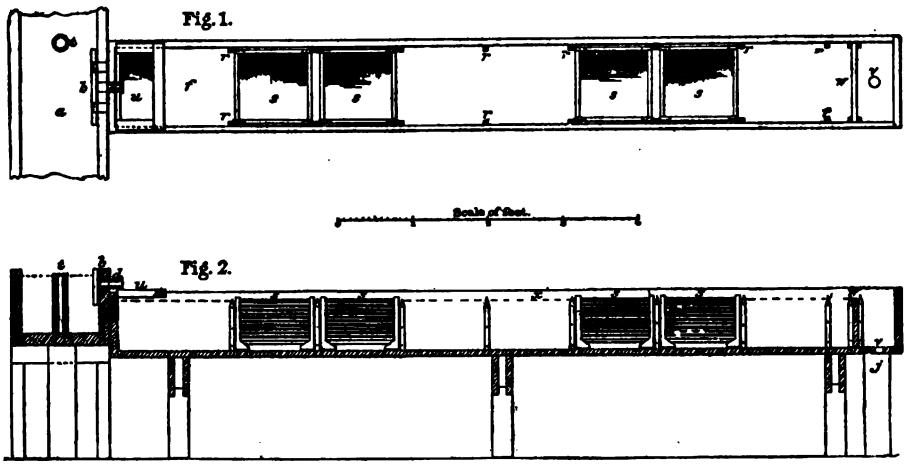
TRANSFER OF EGGS TO THE HATCHERY AND THEIR CARE.

From Dead Brook the eggs are transferred to the hatchery at Craig Brook station, about 2 miles, and spread on trays in the spawning-house. The trays are placed in frames, inclosed in boxes which are padded within to guard against concussion. In spite of all precautions some of the eggs are occasionally killed, though the trays are placed in pans of water and the eggs poured from the spawning-pans with the greatest care. The frames or "stacks" containing the eggs are placed at once in the troughs where they are to be developed.

The trays are 12¼ inches square, and constructed by attaching iron wire-cloth to light wooden rims with blocks at the corners, so that when piled up, one above another, there are narrow interstices on all four sides, through which water circulates freely. The rims of the trays are very slender, in order that they may never have buoyancy enough to float, which would necessitate some means of holding them down and increase the trouble attending their manipulation. Southern poplar (whitewood) is commonly used, and a rim ½ inch wide and ⅜ inch deep answers the purpose well, provided the wire be not very light. The corner pieces are ⅛ inch thick, and give the interstices just enough width to provide an ample circulation of water, but not enough to allow the escape of salmon eggs, which are nearly ¼ inch in diameter. Rusting is prevented by varnishing the wire-cloth with several coats of asphaltum varnish, which works better if made very thin by the use of a large proportion of spirits of turpentine. The same varnish gives a clean and glossy surface to submerged woodwork, and the varnishing is extended to the rims of the trays, the "stack-frames," and interior surfaces of the troughs themselves. Material subject to rust should be used only with great caution. Wire or other metallic forms galvanized with zinc vary in quality. Total loss of eggs has been known to result from the use of galvanized wire-cloth when unvarnished. Careful experiment should precede the use of any particular brand. Tinned wire cloth is better, but whether sufficiently to warrant the extra expense is the question.

In developing eggs, in order to economize room, the trays are piled up 10 or 20 deep in frames that confine them only at the corners and do not hinder the free passage of water horizontally through the "stack." About 2,000 Atlantic salmon eggs are placed on a single tray, and a trough of the ordinary length, 10½ feet, therefore carries 140,000 to 280,000 eggs, with suitable free space at either end. It is therefore an exceedingly compact apparatus and has the further advantage that it can be used in a very plain trough which can, with a few minutes' work, be transformed into a rearing-trough for young fish. For 10-tray stacks the trough is made of pine boards, 12¾ inches wide and 9 inches deep inside, and is set up level, with the top about 30 inches from the floor of the room.

The water is fed into one end through a wooden or rubber tube guarded by a wire screen, and is regulated by a simple swinging gate. The outlet is either over a wooden dam or through a hollow plug, either of which determines the height of the water in the trough, which is always maintained just at the top of the covering tray or an eighth of an inch above it.



Trough Arranged for Eggs.

Fig. 1, plan. Fig. 2, longitudinal section.

a, supply-trough	*j*, down-spout.	*u*, screen.
b, screen.	*r*, cleats.	*v*, outlet.
d, supply-pipe.	*s*, stacks of egg-trays.	*w*, wooden dam.
f, egg-trough.	*t*, waste-pipe.	*x*, water surface.

For the regular picking and cleaning, and for other examinations, the stacks are removed from the trough to a table, where the trays can be taken out one by one, set over into an empty frame, and returned to the trough. This can be performed with ordinary caution at any stage of the development of the embryo, without doing the slightest injury, and after the delicate stage is passed the trays and their burden of eggs can be washed at the same time in a pan of water.

WINTER CARE OF EGGS.

The eggs pass the winter in the stacks. They are regularly picked over and the dead ones removed once or twice a week—twice during the first few weeks, on account of the comparatively high temperature then prevailing and the consequent rapid development of decay and growth of fungus. It depends, to a considerable extent, on the water temperature; the water at the beginning of the spawning season varies from 50° to 55° F., and maintains a mean of 43° to 45° F. during the month of November.

The color of a good egg, or of an unimpregnated egg that still retains its vitality, is a translucent salmon pink, with some variations in shade.

It is possible, by placing it in a favorable light, to get a fairly good interior view, including the detailed anatomy of the embryo. When the egg dies it turns chalky white, becomes wholly opaque, and in a few days, depending on the temperature, decay sets in, and sometimes a white water-mold or fungus begins to grow upon it. The mere decay of the egg would foul the water, thereby injuring the neighboring eggs, and the fungus established on the dead eggs may spread to the living ones. It is therefore essential that the white eggs be removed before they have time to do any injury.

For egg-picking a homemade pair of tweezers, about 6 inches long, is used, made of any convenient wood and tipped with a pair of wire loops of a size to conveniently grasp the egg. The operator lifts the stack of trays carefully from the trough and, to save dripping, carries it on a wooden waiter to a well-lighted table of convenient height, on which stands an oblong pan, 14 by 18 inches, holding about an inch of water.

The stack of eggs to be picked is placed at one end of the pan and at the other end is an empty stack-frame. The trays are examined one by one, dipped in the pan of water, picked (or cleaned by agitation when the eggs are in condition to endure the disturbance), and placed in the empty frame. The air of the room is kept at a low temperature during this process, and the water in the pan is often changed.

The eggs when first impregnated are very sensitive to rude shocks and are handled with great care. Within a few hours the germ begins to develop; in 10 days, at a temperature of about 40° F., the germ-disk appears as a ring of color on the upper side of the yolk. At this date the unimpregnated egg presents the same appearance and does not change much until its death, however long that may be deferred. In the impregnated egg, however, the germ-disk continually enlarges upon the surface of the yolk; the ring of color that marks its edge advances before it, passing quite round the yolk, and closing up on the posterior side.

As early as the thirteenth day the difference between the impregnated and unimpregnated egg is quite plain to the unaided eye after a very little experience, and three or four days later the good egg is marked by a distinct line of color passing around the very middle of the yolk, a phenomenon never appearing in an unimpregnated egg. During this stage, while the embryonic disk is spreading around the yolk, the egg grows constantly more and more delicate, and liable to rupture of its tissues and consequent death on very slight disturbance; but later the tissues grow stronger, and when, about the thirty-fifth or fortieth day, the eyes of the embryo have assumed enough color to appear as two dark dots, the egg has attained hardiness enough to endure rougher handling. Thenceforward, until the near approach of the time for hatching, the work consists simply in picking out the dead ones, occasionally rinsing out the sediment, and sometimes removing the unimpregnated eggs.

PICKING OUT DEAD EGGS.

PACKING SALMON EGGS.

HANDLING EGG-TRAYS.

The latter procedure is attended to for the entire stock of eggs, but is of special importance in case of those that are to be transported. It may be performed any time after the good eggs become hardy—that is, after the eyes become black—but becomes easier late in the season. The unimpregnated eggs, which were at first fully equal in hardiness to the impregnated, lose in that respect as time passes, and finally are readily killed and turned white by a shock which does no injury to the impregnated eggs. When this time has arrived, the eggs are turned from the trays into spawning-pans with a moderate quantity of water, and poured from pan to pan back and forth a dozen times, each time falling a foot or more, and striking the bottom of the pan with considerable force, giving each egg a severe shock. They are then returned to the trays and troughs and as soon as convenient are picked, and if the operation has been thorough almost every unimpregnated egg has turned white and is picked out, while the eggs in which the embryos are developing have not suffered at all.

PACKING AND TRANSPORTING.

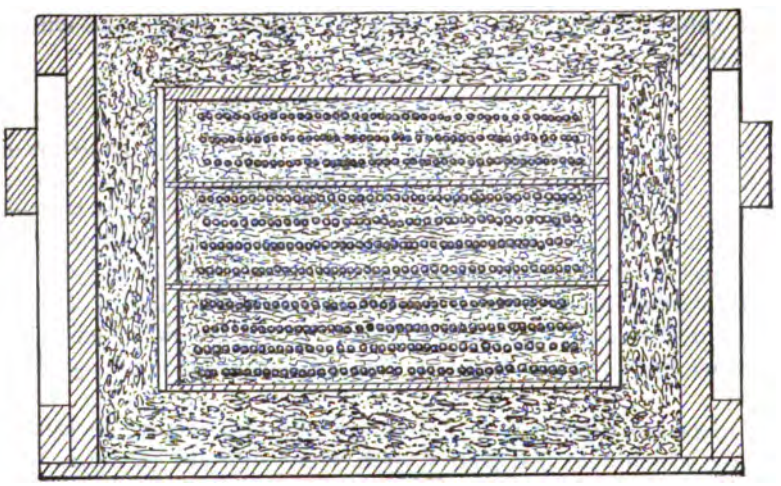
Eggs may be safely transported as soon as the eyes have become thoroughly colored, and until within a few weeks (five or six in cold weather) of the date for hatching. In shipments made too late the shells burst on the way and the embryos perish. The method of packing eggs at Craig Brook is to put them in layers alternating with wet sphagnum moss in shallow wooden boxes, placed in cases of a size to afford on all sides of the inner package a space of 2½ or 3 inches, which is filled with some light, porous material that will form a good nonconductor of heat.

The eggs are thrown from hatching-trays into a large rectangular pan, from which they are poured with water into tin measures which hold 2,500 each. A thin layer of moss is placed in the bottom of a packing-box. A little fine snow is sifted upon the moss, and on this is spread a piece of mosquito netting that has been soaked and rinsed in clean water. A measure of eggs is now poured on and spread out and covered by folding over the edges of the netting, which now completely envelops them. Next a layer of moss is spread, followed by snow, netting, and eggs, as before, and the series is repeated until the box is full. The moss must be sufficiently wet, so that with the melting of the snow it shall have all the moisture it will hold, and no more, as it is very desirable to avoid the wetting of the outer packing. If the moss is too dry, the eggs may dry to the extent of becoming indented, and the same result may come from crowding the moss in too hard on the eggs, though it should be pressed in so tightly that the eggs will not slide out of place if the case is turned for a moment on its side.

The temperature of the packing-room is below 50° F., and packing materials are kept in a place which is cool, yet not much below the freezing-point. Salmon eggs packed as above commonly go a three days' journey without completely melting the snow that was sprinkled

under the eggs, and on several occasions eggs of landlocked salmon have been carried across the Atlantic in prime condition, without repacking or special attention.

The packing-boxes are made of thin pine or fir, 12 inches wide and 15 inches long—⅜-inch thick boards being used for the end pieces and ¼-inch for the other parts—and hold in a single layer, without crowding, 2,500 eggs. The deepest are 3½ inches deep and take four layers, or 10,000 eggs, in a box. To make up a shipment of 40,000 eggs, four boxes are piled up and secured together by tacking strips of wood against the ends, with a cover on the upper box, and this package placed in the case. For a shipment of 80,000, two of the 40,000 packages are put side by side in a larger case, and the proportions selected for the inner boxes are such that the case required is of convenient form.



Longitudinal section of a case of Atlantic Salmon eggs.

Different mosses can be used for packing, but none are so good as the sphagnous moss that can be found in swamps and bogs in most regions of high latitude or considerable elevation. Fresh moss is preferable for a bed for the eggs, though dead, dry moss may be moistened and used with good results.

The moss is gathered in August or September, dried on the ground, and stored in sacks or in bulk until wanted. It retains its freshness through the following winter, not heating like most organic materials. It is exceedingly light, and the best nonconductor known, with the possible exception of asbestos. It is used dry in the outer packing, mainly to save weight, but when protection against freezing is all that is sought, wet moss is better, as frost penetrates wet moss more slowly than dry. When moss can not be had, there are many substitutes which may be used for the protective envelope, such as dry forest leaves, chaff from a haymow, chopped hay, or even crumpled paper; but the latter should not be allowed to become wet.

HATCHING.

As the time for hatching draws near, the eggs are placed on trays provided with legs or some other support to keep them up from the bottom of the trough. Brass nails driven into the under sides of the tray rims are good temporary legs, and after the hatching is over they are readily removed and the necessity of a special set of trays for hatching is avoided. When there are plenty of troughs, these trays stand singly on the bottom of the trough, but when it is necessary to economize room two or even three are disposed one above another. When no necessity exists for economy of space, 4,000 eggs are allowed a whole trough, which is at the rate of 400 to the square foot; 2,000 or even 5,000 to the square foot may be carried through hatching and the entire sac stage, but the latter number involves risky crowding.

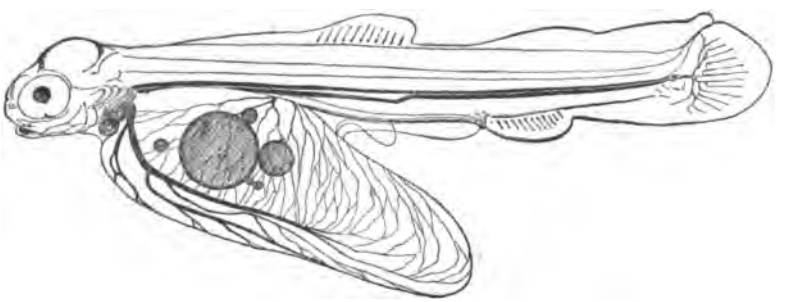
The hatching is sometimes expedited by giving eggs that are just at the hatching point a decided shock, similar to that given at an earlier date to kill the unimpregnated ones; also by the temporary stoppage of the water supply. But at Craig Brook it is the custom to lay the eggs out in good season and allow them unlimited time in which to hatch, sometimes a week, sometimes two weeks. The earliest lots commonly hatch the latter part of March, and it is not often that any remain unhatched after April 20. The mean duration of the egg stage is therefore about 157 days, during which the mean temperature of the water has been about 37° F. While hatching is progressing, the outlet screens are closely watched to keep the empty shells from clogging them up; for when a considerable part of the screen is clogged the force of the current through the open spaces is greatly increased, and the soft and yielding sacs of the fish are liable to be drawn through the meshes.

THE SAC STAGE.

When the shell breaks, though it has been coiled up in a space less than ¼ inch in diameter, the trunk of the newly hatched salmon at once straightens out to a length of about ¾ inch. The yolk, scarcely diminished from its original size, hangs beneath and constitutes the greater part of the bulk of the fish. The young salmon is for a while more unwieldly than a tadpole. When frightened he sculls about with great energy, but makes slow progress and is fain to lie on his side on the bottom of the trough or crowd with his companions into a corner. The sac is a store of nutriment, which is gradually absorbed into the other parts of the fish; and so long as it lasts the young salmon will not eat. The interval between hatching and total absorption of the sac varies with the temperature, the mean at Craig Brook in April and May being about six weeks.

As time passes the embryo fish grows more and more to resemble the adult, his body acquires strength, and his fins assume form and become more effective as organs of propulsion. At last his digestive system

assumes its functions and rouses the desire for food. Until this time, intent only on hiding, the fry have clung obstinately to the bottom and to the dark corners, but now they scatter about through the water, with heads upstream, watching for prey. This indicates that they must be fed. During this period of his growth it is simply necessary to see that the young fish has plenty of water, that there is no hole or crevice into which he can be drawn by the current, and that he is protected from enemies, such as large fishes, minks, rats, kingfishers, and herons. If not in a house, well-fitting covers must be provided to the troughs and impassable screens command both ends. The screens are of fine wire-cloth, 12 or 14 meshes to the linear inch, and present a surface of 14 square inches to each gallon of water passing through them each minute. Thus, if there are 4 gallons of water passing through the trough each minute the portion of the screen beneath the surface of the water must measure as much as 56 square inches, and if the screen is 12 inches wide the water must be $4\frac{2}{3}$ inches deep on the screen.



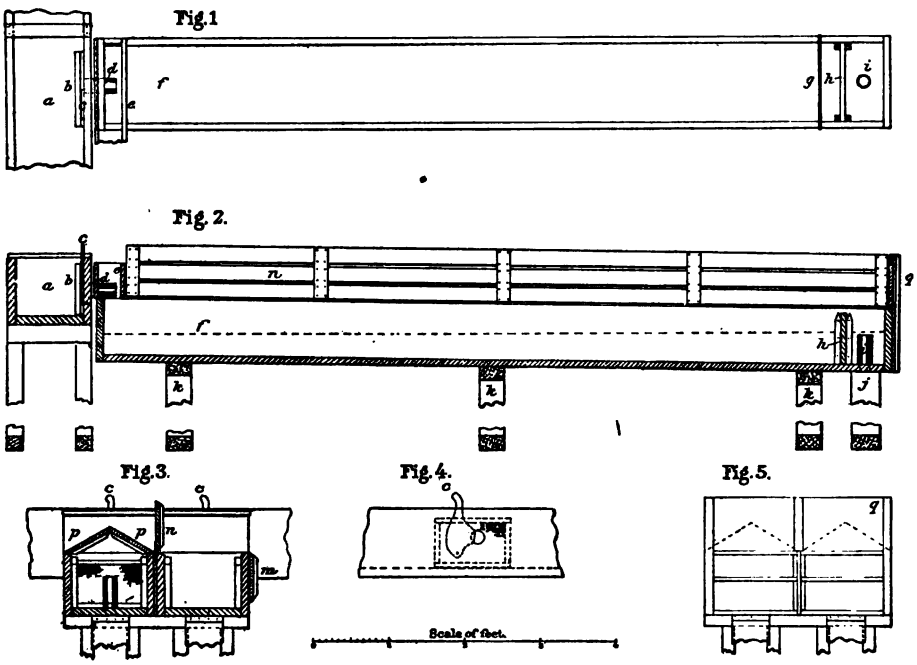
Atlantic Salmon, recently hatched.

REARING.

The leading feature of the work of the station is the rearing of fry to the age of six or eight months. The fishes reared are mainly Atlantic salmon, but landlocked salmon, American brook trout, European brook trout, rainbow trout, steelhead trout, American lake trout, Swiss lake trout, Scotch sea trout, and saibling have also been handled. The fish are fed wholly on artificial food from about June 1 till October or November, when they are mostly liberated. To a limited extent they are kept in artificial ponds, but troughs of the same form and dimensions as those already described for use in developing the eggs and in hatching have given satisfactory results and have been adopted for the most part. Each trough is provided with a changeable outlet screen and below the screen discharges the water through a hole in the bottom, into which is fitted a hollow plug, the height of which determines the depth of water in the trough. The hollow plug plays an important part in the daily cleaning of the trough, which will be referred to further on.

The use of the troughs in the open air, which, in the absence of commodious buildings, is a necessity, compels the constant use of covers to keep out vermin; and wooden covers in pairs, running the whole length

of the trough, hinged to its sides, and, when closed, assuming the form of a roof at an angle of 45°, were finally adopted. These covers are made of thin boards, ⅝ inch thick, sawed in narrow pieces, which are put together so as to leave in each corner two cracks open ¼ inch wide for the admission of light when the covers are closed. When open they may be fixed in an upright position, thus increasing the height of the sides and guarding against the loss of fish by jumping out.



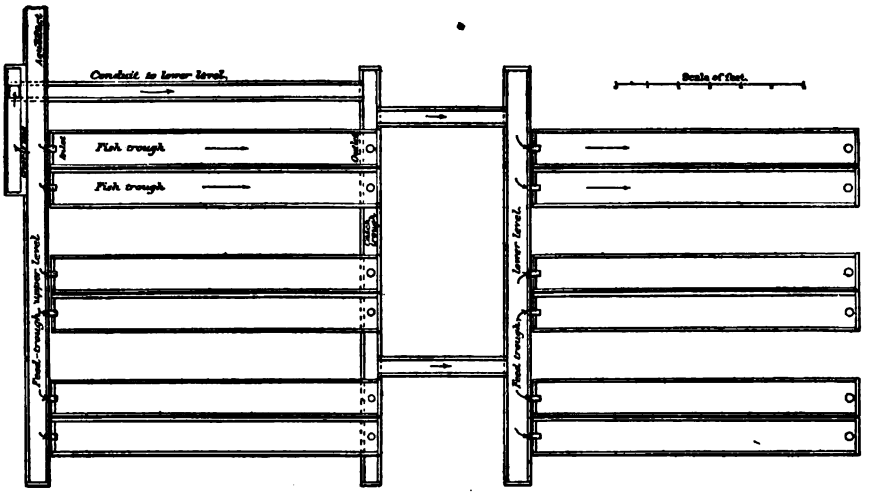
Troughs arranged for Rearing.

Fig. 1, plan. Fig. 2, longitudinal section. Fig. 3, cross-section near foot of trough. Fig. 4, inlet, with rocking gate. Fig. 5, elevation of lower end.

a, supply-trough.
b, screen.
c, rocking gate.
d, supply-pipe.
e, water-board (to spread the water and throw it down).
f, fish-trough.
g, gripe, to prevent spreading of sides.
h, outlet screen.
i, hollow outlet plug.
j, down-spout.
k, supports.
l, cover.
m, cover open (hanging).
n, cover open (upright).
p, cover closed.
q, end boards (closing aperture).

Water is furnished through rubber or wooden pipes ¾ inch in diameter, and the bore of the hollow plug at the outlet is 1¼ inch or larger. The inflow is regulated by an oscillating or rocking gate, which is set to admit the desired volume of water. The trough is set with the upper end an inch or two higher than the other, to facilitate cleaning out, and the water is kept during the summer about 4 inches deep at the lower end.

The troughs are supported by a suitable framework at a convenient height from the ground and arranged in pairs with their heads against a long feed-trough, constructed of pine boards and perforated on the side by the feed-pipes, over each of which is a capacious screen to prevent clogging by leaves or other floating debris. A frame 6 by 12 inches, covered on its outer side by wire-cloth of ¼ inch square mesh, answers the purpose of a screen so well that water from an ordinary brook can be admitted to the feed-trough without previous filtering or screening and with little or no danger of a stoppage of water in any of the fish-troughs. Such screens over the feed-pipes might be made the sole dependence, were it not that the labor attending their cleaning would be greater than that required by a separate filter or screen.



Stand of Troughs for Rearing Atlantic Salmon.

The system represented here by 12 troughs in two series may be extended to many hundreds of troughs in four (or more) series, each series on a different level and receiving water from the series next above, the fall from one to another being about 4 feet. In the drawing the series of 6 troughs on the left is supplied with water directly from the upper "feed-trough" (i. e., supply-trough), and they discharge into a catch-trough, from which the water is carried to the supply-trough ("feed-trough") of the lower level. If the aqueduct supplies more water than the upper series of troughs can use, the surplus passes by way of the "overflow" directly to the catch-trough and thence to the supply-trough of the second series. With a fall of 4 feet, the catch-trough and the conduits that lead from it are below the walks which give access to the troughs on both sides and at the lower end.

The number of fish assigned to a single trough is ordinarily 2,000, and the volume of water given them is commonly 5 gallons per minute. Generally the water is used but once in troughs and is discharged

into conduits leading to ponds where larger fish are kept; but a stand of 100 troughs has lately been set up with the design of using all the water twice; and for many years there has been one system of 52 troughs, arranged in four series, which use in succession the same water, the young salmon thriving quite as well in the fourth series as in the first.

On one occasion a few of them were maintained for several weeks in the warmer water of a neighboring brook, where a trough was set up and stocked with 100 young salmon taken from one of the troughs at the station July 30. The temperatures observed between 1 and 4 p. m. in the fish-trough on successive days from July 30 to August 14, not including August 1 or 10, were as follows: 79°, 75°, 77°, 79°, 82°, 82°, 78°, 76°, 76°, 76°, 74°, 74°, 74°, 74°, F.

The fish were fed the same as the lot out of which they were taken, except that they received food only once a day instead of twice, and were returned to the station October 7 without a single loss during the experiment. Moreover, they were all weighed October 10 and found to average 100.6 grains, while those of the original lot that had remained at the station, with a temperature between 50° and 71° F., averaged only 56.1 grains. While the greatly increased weight of the fish kept in the stream was owing in part to more space, as the 100 had as large a trough as 1,505 at the station, the higher temperature was undoubtedly one of the factors that contributed to the gain in weight, and it is at least plainly shown that the warm water was not unhealthful.

Though small ponds, excavated by the former proprietor, were in existence at the station and used to some extent for rearing young fish in their first summer as far back as 1888, and older fish have been kept in small ponds each season since that, it was not until 1896 that enough pond work was done to furnish data of importance.

The ponds for rearing Atlantic salmon are among the series known as the "south ponds," occupying a smooth piece of ground sloping toward Alamoosook Lake at a grade of 1 in 8. Formerly it was mostly a swale, watered by a copious spring at its head. This series comprises 19 ponds of rectangular form, about 50 to 90 feet long and 15 feet wide, with a depth of 2 or 3 feet. The water supply of those used for Atlantic salmon is derived from Craig Brook by an aqueduct tapping it at a point where two parts of Craig Pond water are mingled with one part spring water, being substantially the same as the water supplying the most of the rearing-troughs. From 5,000 to 10,000 fish that have been fed in troughs during the early part of the feeding season are placed in each pond, and for the remainder of the season are fed the same food that is given to the fish left in the troughs; and the results indicate that the stock of fish might be safely increased.

While the greater part of the salmon reared at Craig Brook are liberated in October, when about seven months old, in 1891–92 about 16,000 were carried through the winter, most of them in tanks sunk in the ground, and nearly as many have been wintered some other

seasons. Fish may also be kept all winter in troughs in the open air by occasionally spreading blankets over them in exceptionally cold weather, and keeping the conduits carefully covered.

The fish surviving the summer season are generally counted and weighed in October, in the following manner: A large number of them are dipped up from a trough in a small dip net made of cheese-cloth, and from this, while it is hanging in the water in such a manner that the fish can not escape, they are dipped out a few at a time, in a small dipper or cup, counted, and placed in another bag net until a sufficient number (generally 200) are counted, when they are lifted out of the water, held a moment in the air to drain, and all turned quickly into a pail of water which has previously been weighed. With care no appreciable amount of water goes with the fish, and the increase in the reading indicates their weight with a fair approach to accuracy, and with care and celerity of action it is quite safe for the fish.

The size attained by the fish varies greatly, being affected by the water, the space allowed, the feed, and perhaps by hereditary influences; but when seven months old a trough-reared salmon is generally from 2½ to 3 inches long and weighs from 35 to 100 grains, the maximum being about 130 grains and the minimum as low as 7 grains, the general mean for 1896 being 45.8 grains. Salmon reared in ponds have been far more thrifty, their general average in 1896 being 101 grains.* The losses in ponds from July to October were rather heavy, being 11.7 per cent, owing to depredations of frogs, birds, and cannibal fish. The losses in the troughs during the entire season were 9.1 per cent, but most of these were in the early stages of fryhood. After July losses in troughs are always very light.

MATERIALS FOR FISH FOOD.

At Craig Brook station there have been used butchers' offal, flesh of horses and other domestic animals, fresh fish, and maggots. Experiments have also been made with pickled fish, blood, fresh-water mussels, mosquito larvæ, miscellaneous aquatic animals of minute size,

*A very interesting comparison between the results of rearing in troughs and ponds is afforded by the record of two lots of steelhead trout during the season of 1896. All the fry of this species that were devoted to rearing were fed in troughs until July 22, when some of them were transferred to a pond which has an area of about 1,100 square feet and another lot was kept in a trough. The two lots were fed exactly alike, about one-sixth of their nutriment being live maggots, and five-sixths chopped meat, liver, and other butchers' offal. November 7, the lot in the trough was overhauled, and the 762 survivors found to weigh 10 pounds 4 ounces, or an average of 94 grains. Three days later the pond fish were seined out and the 7,398 survivors found to weigh 235 pounds 10 ounces, an average of 223 grains. It is not believed that natural food occurring in the pond contributed much to this result, and it would appear that the controlling factor in the case was the space afforded the fish. Leaving out of the account the difference in depth, in the pond there were less than 7 fish to each square foot of area, while in the trough, which had an area of about 11 square feet, there were to each square foot 69 fish. A similar illustration was furnished by 41 rainbow trout of the hatching of 1896 that got astray in one of the ponds and were taken out November 11, weighing 480 grains each. Those of the same age, reared in troughs, attained during the season only a weight of 136½ grains each.

flour, and middlings. The butchers' offal comprises livers, hearts, and lights, which are collected from the slaughter-houses twice or thrice weekly, and preserved in refrigerators until used.

The flesh of old and worn-out horses has been used each year since 1892 in the same way as the butcher's offal, with very satisfactory results; the parts that could be chopped readily have been fed direct to the fish so far as needed, and other parts have been used in the rearing of maggots.

Next to chopped meat maggots have constituted the most important article of food, and their systematic production has received much attention. A rough wooden building has been erected for this branch of the work, and one man is constantly employed about it during the summer and early autumn months. The maggots thus far used are exclusively flesh-eaters, mainly those of two undetermined species of flies; the first and most important being a small, smooth, shining green or bluish-green fly, occurring in early summer and remaining in somewhat diminished numbers until October; and the other a large, rough, steel-blue fly that comes later and in autumn becomes the predominating species, having such hardiness as to continue the reproduction of its kind long after the occurrence of frosts sufficiently severe to freeze the ground.

To obtain maggots meat is exposed in a sheltered location accessible to flies during the day. When well stocked with the spawn of the flies it is placed in boxes, which are set away in the "fly-house" to develop; when fully grown, the maggots are taken out and fed at once to the fish. Stale meat, parts of the butchers' offal and of the horse carcasses not adapted to chopping; fish, fresh, dried, or pickled; fish pomace from herring-oil works, and any animal refuse that comes to hand, are used to entice the flies and afford nourishment for the maggots. Fresh fish, when not too watery or oily, like alewives and herring, is very attractive to the flies, and in proper condition may serve as well as fresh meat. Fish dried without salt or smoke and moistened before using is, when free from oil, a superior article. Its preparation presents some difficulties, but in winter it is easily effected by impaling whole fishes on sticks and hanging them up under a roof where they will be protected from rain without hindering the circulation of the air; in this way many flounders and other refuse fish from the smelt fisheries have been dried.

It is usually necessary to expose meat but a single day to obtain sufficient fly spawn; the larvæ are hatched and active the next day, except in cool weather, and they attain their full growth in two or three days. To separate them from the remnants of food the meat bearing the fly spawn is placed on a layer of loose hay or straw in a box which has a wire-cloth bottom, and which stands inside a slightly larger box with a tight wooden bottom. When full grown, the maggots work their way down through the hay into the lower box, where they are found nearly free from dirt.

When young salmon or trout first begin to feed they are quite unable to swallow full-grown maggots, and small ones are obtained for them by putting a large quantity of fly spawn with a small quantity of meat, the result being that the maggots soon begin to crowd each other and the surplus is worked off into the lower box before attaining great size. No attempt is, however, made to induce the young fish to swallow even the smallest maggots until they have been fed a while on chopped liver.

Maggots are produced and used in considerable numbers, sometimes as many as a bushel in a day. The fish eat them eagerly, and appear to thrive on them better than on dead meat. Having great tenacity of life, if not snapped up immediately by the fish they remain alive for a day or two, and, as they wriggle about on the bottom, are almost certain to be finally eaten, which is a great gain in cleanliness and economy, as the particles of dead flesh falling to the bottom are largely neglected by the fish and begin to putrefy in a few hours and foul the troughs. As the growth of maggots can be controlled by regulation of the temperature, they may be kept all winter in a pit or cellar and used as food for fish confined in deep tanks not easily cleaned.

In the rearing of maggots the offensive odors of decaying flesh may be partly overcome by putting it away in boxes, after the visits of the flies, and covering it with pulverized earth. Only flesh-eating maggots have yet been tried, and the trouble may possibly be rectified by cultivating the larvæ of other species, such as the house-fly, the stable fly, etc., or a little white maggot known to grow in heaps of seaweed, if their rate of growth is found to be satisfactory.

Occasional use has been made of fresh fish for direct feeding, but when thrown into the water after chopping it breaks up into fibers to such an extent that it is not satisfactory, unless in a coarsely chopped form, for the food of large fish. A few barrels of salted alewives have been used, and, if well soaked out and chopped, they are readily eaten by the larger fish and can be fed to fry, but are less satisfactory with the latter, and, like fresh fish, break up to such an extent that they are only to be regarded as one of the last resorts.

Fresh-water mussels, belonging almost wholly to a species of *Unio*, have been occasionally gathered with nets or dredges in the lake close to the station and opened with knives and chopped. The meat is readily eaten by all fishes and appears to form an excellent diet. It is more buoyant than any other article tried, sinks more slowly in water, and gives the fish more time to seize it before it reaches the bottom; but the labor involved in dredging and shelling is a serious drawback.

During the seasons of 1886 and 1888 some use was made of mosquito larvæ, collected from pools of swamp water by means of a set of strainers specially devised for the purpose and from barrels filled with water disposed in convenient places near the rearing-troughs. The larvæ (or pupæ) were strained out and fed to the fish. No kind of food has been

more eagerly devoured, and apparently no other food has contributed more to the growth of the fish; but the time expended in collecting is out of all proportion to the quantity of food secured. Perhaps a series of breeding-tanks arranged in proximity to the fish-troughs, into which the water containing the larvæ might be drawn when desirable by the simple opening of a faucet, would reduce the labor involved.

Middlings and flour have been tried in combination with blood from the shambles, but did not appear to satisfy the fish so well as the various forms of meat, and their use has, therefore, not been continued. They were fed in the form of a pudding composed of two parts blood and one part flour or middlings, cooked carefully to avoid burning, and the mixture was then passed through a meat-chopper and ladled out with a spoon, like other chopped food.

The growth of live food in the ponds themselves in which the fish are maintained has been the subject of study. Ponds several years old and well stocked with vegetation were at one time devoted to these experiments. They had been empty during the preceding winter, and in the spring were fertilized with various sorts of animal and vegetable refuse. They were stocked with different species of crustacea native to the region, including shrimps (*Gammarus*) and entomostraca, of the genera *Daphnia*, *Ceriodaphnia*, *Sida*, *Cyclops*, *Polyphemus*, etc., which were systematically collected from open waters by nets and other apparatus and placed in the ponds. These forms all multiplied there, some of them enormously, but no means was found of inducing continuous or frequent reproduction of them, and the young fish soon exhausted the supply.

In serving the food the attendant carries it with the left hand—in a 2-quart dipper if chopped meat, in a larger vessel if maggots—and, dipping it out with a large spoon, strews it the whole length of the trough, being careful to put the greater portion at the head, where the fish nearly always congregate. Finely chopped food, for very young fish, is slightly thinned with water before feeding.

It is usual to feed the meat raw except the lights, which chop better if boiled first; but occasional lots of meat, on the point of becoming tainted, are boiled to save them. All meats fed directly to the fish are first passed through a chopping-machine. To fish just beginning to eat, food is given four times a day, or in some cases even six times, but as the season progresses the number of rations is gradually reduced to two daily. In winter such fish as are carried through are fed but once a day.

CLEANING THE TROUGHS.

The troughs are all cleaned daily. When the hollow plug is drawn the water rushes out rapidly and carries most of the debris against the screen. The fishes are excited, and, scurrying about, loosen nearly all the dirt from the bottom; what will not otherwise yield is started with a brush, but after the first few weeks the brush has rarely to be used

except to rub the debris through the outlet screen. Owing to the inclination of the trough, the water recedes from the upper end until the fishes lying there are almost wholly out of water, but, although they are left in that position sometimes for 10 or 15 minutes, no harm has ever been known to result.

TRANSPORTATION AND LIBERATION OF YOUNG SALMON.

The salmon produced at the station have, with few exceptions, been liberated in the Penobscot River or its tributaries, and more than 90 per cent of them in small tributaries within 10 miles of the station. They have been spread about in streams and lakes, at all accessible points. They are transferred in tin cans, holding about 8 gallons, with an extreme height, including neck, of 17 or 18 inches, and a body 15½ inches in diameter and 10 inches deep, making a very broad and low can, well adapted to the use to which it is put. Its great width favors aeration at the surface, and a good deal of dashing about of the water when on the road. The cans are filled to within about an inch from the shoulder, giving opportunity for the water to swash about and aerate itself. Into such a can are put from 200 to 400 Atlantic salmon seven months old, more or less, according to the size of the fish, the temperature of the air, and the weather. The ordinary load is about 300 when the temperature of the water is 52° to 54° F., making 37 fish per gallon. Such loads are entirely safe for the conditions attending the work. The motion of the wagon in which they are carried keeps up the aeration of the water, so that the fish can not exhaust the air. Should the cans stand still a very long time aeration is effected by a force-pump which draws the water from the can and returns it through a tube so that it strikes upon a deflector by which it is broken and scattered in spray. The suction hose is covered with a roomy wire strainer, so that the fish are not drawn in.

DISEASES.

Salmon in all their stages of growth are subject to a variety of diseases. White spots sometimes occur on the eggs attached to the shell, but have no hold on the embryos, so that when the shell is torn off the white spot is seen as a cluster of globular white masses on its inner surface. These appear to be vegetable parasites, perhaps fungoid in their relations, and are never seriously abundant. Other white spots are connected with the yolk-sac itself. These are more serious, but while they result in the death of many embryos, they are by no means always fatal. In 1896 there were hatched at the station some rainbow trout that were badly spotted on the sac. A portion of the fry were divided into three lots for experiment: (*a*) Without spots; (*b*) moderately spotted; (*c*) badly spotted. They were kept separate through the season, and a fair percentage survived, as follows: Of lot *a*, 55 per cent; of lot *b*, 59 per cent; of lot *c*, 43 per cent. In the fall they were

all weighed, and it was found that lot *c* had made a slightly better growth than lot *a*.

One of the most uncontrollable diseases attacks salmon fry midway in the sac stage, and finishes its work before the complete absorption of the sac. The most evident symptom is the appearance of scattered white spots in the sac; the fish cease to try to hide, but lie scattered about on the bottom of the trough; the spots increase in size, coalesce, and finally occupy large areas, especially in the tip of the sac, which becomes quite white. Soon after this the fish dies. The attack on a lot makes rapid progress; for instance, a lot of 2,000 in which, up to April 22, the losses had been from 1 to 9 daily, showed 17 dead on the 23d, and five days later 360 died in a single day. In 1890 this epidemic attacked especially the fry of Atlantic salmon, destroying about a third of them; it also destroyed many landlocked salmon, and some other species suffered heavily about the same time. In 1891 there was not a trace of it. In 1892 it returned again, and out of 305,353 fry of Atlantic salmon it left but 3,874, and these were by no means healthy; but it attacked only Atlantic salmon. Salt and mud were tried as remedies, but though the progress of the disease appeared in some instances checked thereby, no permanent benefit resulted from their use.

In 1890 this epidemic appeared to run in families. There was evidence tending to show that all the eggs coming from a particular mother would have a common degree of liability to the disease—some families being exterminated by it, some only decimated, and others able to resist it altogether. It did not appear to be infectious, as several lots of fry, separated by screens, would occupy a single trough, and in some cases those at the head of the trough would be totally destroyed, or nearly so, and those below them escape from attack.

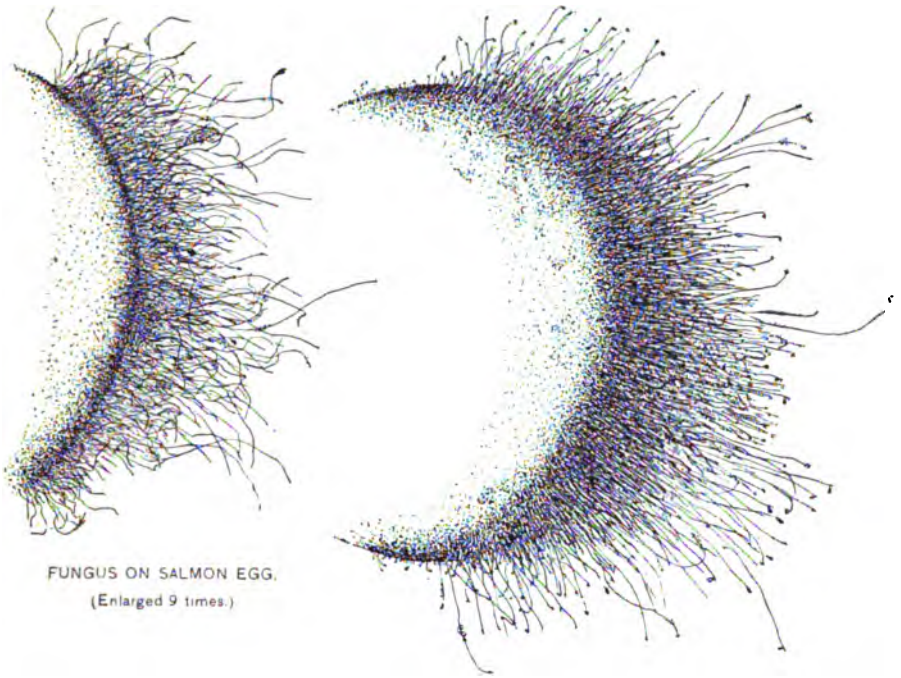
The only other diseases of Atlantic salmon that demand notice here are connected with the so-called fungus, belonging to the group of water molds called *Saprolegniæ*, and probably to the genus *Saprolegnia*, one species of which, *S. ferax*, is noted as the cause of very destructive epidemics among the adult salmon of Scotch and English rivers. The species that attacks fish eggs is well known to every fish-culturist as a fine white growth of a cottony or woolly appearance that forms upon dead eggs, and when neglected spreads out so as to envelop in its threads a great many of the living eggs surrounding it. It is by no means certain that all such growths belong to one species or even to one genus, but they are much alike in structure and growth and live upon animal and vegetable matter, either as parasites attacking living matter or as saprophytes attacking only dead and decaying matter. There has never been serious trouble with this fungus at Craig Brook station, and great loss from it can only occur in consequence of neglect of the duty of picking out the dead eggs. An instance of its attacking a living egg except by reaching out from a dead one is unknown. Fish

several months old are sometimes afflicted with a similar growth, which may possibly be not the original cause of the disease, but only an attendant symptom. Such an attack was experienced at Craig Brook in July, 1888. The fry of Atlantic salmon were the sufferers and the mortality was considerable, but it yielded promptly to a salt bath.

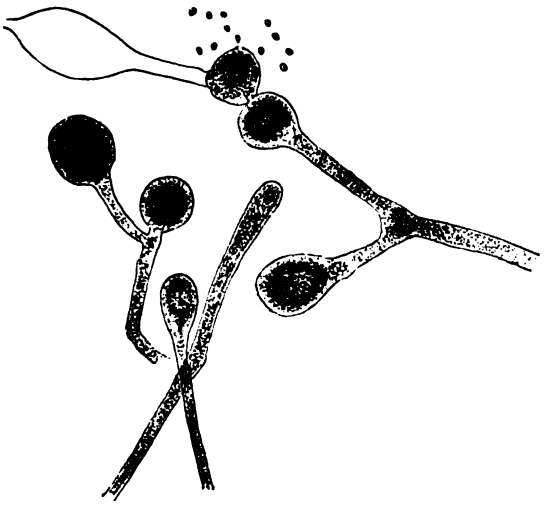
The occurrence of fungus on wounds, even on such as result from the abrasion of the skin or the loss of a scale, is very common, but such cases are rarely fatal, though no remedy be applied. The only serious attack of fungus on adult salmon occurred during the experimental work at Craig Brook in 1871. The first inclosure made to receive the breeding fish was a small and shallow one, made by damming the brook itself at a point where its volume consisted of about 30 per cent of spring water. The fish had suffered considerably from the handling necessary in bringing them so far and from the rough character of the experimental cars in which they were transported. The first of them were placed in the inclosure June 8. On the 12th 2 of them died, on the 13th 2 more, and by the 17th 14 were dead out of 41 received; by the 20th the mortality had increased to such a point that it became evident that not a single salmon would survive unless some change was made in the mode of confining them, and they were all removed and placed in other quarters. Nine of them, already so badly diseased as to be considered hopeless cases, were turned loose in Craig Pond, and part of these recovered and spawned in the autumn following on a gravelly shore, where some of them were taken and found to bear the well-healed scars of their ugly sores.

The symptoms noted were sluggishness and heedlessness; an inclination to swim near the surface of the water; a white, filmy appearance of the eyes, which seemed to be accompanied or followed in many cases by blindness; a white fungoid growth on the abraded tips of the fins and wherever the scales had been rubbed off; white blotches breaking out on all parts of the body, even where there had been no mark of injury, particularly on the head, proving on examination to be patches of white fungus, which, on the parts of the body covered by scales, grew underneath the latter and pushed them from their places.

Experiments in confining salmon in other waters the same season turned out successfully, and it seems that the most important conditions in the case were these: The area of the fatal inclosure was about a quarter of an acre; the water was partly from springs and was so exceedingly transparent that a pin dropped into it could be readily seen at a depth of 6 feet, so that there was practically no protection from the rays of the June sun; the fish had been transported in a common dory with holes bored in the bottom to admit water, a very inferior sort of car compared with those now in use; they had been transported a long distance and passed three separate locks and had finally been hauled in a tub on a cart over rough ground from Alamoosook Lake to the inclosure.



FUNGUS ON SALMON EGG, BEARING REPRODUCTIVE ORGANS.
(Enlarged 9 times.)



REPRODUCTIVE ORGANS OF EGG FUNGUS.
(Enlarged 150 times.)

The conditions at Craig Pond, where some of the worst cases recovered, were these: An area of 231 acres; a maximum depth of 69 feet; exceedingly pure and transparent water, like that of the inclosure.

At two of the other inclosures tried that summer, where there was no attack of fungus, the water was brown and dark, like that of ordinary brooks and ponds, and in the remaining one it was intermediate in character.

These facts point strongly to the character of the water as the cause of the fatality of the disease, and especially to its pellucid character, which exposed the salmon to an extraordinary glare of light, whereby the growth of the pest was greatly encouraged. The recovery in the transparent water of Craig Pond was rendered possible by the great depth of the water, through which but a small fraction of the light of day could penetrate. No doubt the salmon liberated there at once took refuge in the deeper parts. The suggestion naturally arises that artificial shade might be useful in the treatment of such diseases, whether the attacking fungus be identical with that observed in the above instances or a related one.

It is certain, from the promptness with which dead animal matter becomes the prey of saprophytic growths, that the spores of these water-molds are well disseminated throughout fresh waters, everywhere ready to seize upon an opportunity for germination and growth, and that as a general rule these spores are quite unable to seize upon any animal substance which is not already dead or in a diseased condition.

A growth of *Saprolegnia ferax* once established on the body of a salmon is able to extend itself upon and into the living tissues around it, which it seizes upon and destroys. Growing upon a dead egg, it not only ensnares the neighboring living eggs, but sometimes pierces their shells and establishes itself on the internal parts. In one instance the fungus had gone so far as to attach itself to a living embryo, which, on removal from the shell, was found to support on the sac quite a tuft of growing fungus, though neither on the sac nor any other part of the fish was a trace of dead substance discernible.

It has been ascertained that the *Saprolegnia* which attacked the living salmon can be communicated by contact to dead flies, and that *Saprolegnia* found growing in the ordinary way on dead flies in water can be communicated in its turn to living and healthy dace and may so flourish on them as to cause their death.

The impression has prevailed that the *Saprolegnia* which infests the eggs in hatching-troughs originates in or is encouraged by bare wood exposed to water, and that special effort is necessary to prevent its forming; but experience at this station does not show that attacks of fungus on either eggs or fish could be traced to bare wood, and, on the other hand, eggs and fish in troughs carefully varnished with asphaltum are no freer from fungoid or other disease than those in neighboring troughs from which long use had worn almost the last vestige of varnish.

The best precaution against this growth is the careful picking out of dead eggs before there is time for the fungus to grow on them, and in case of a serious attack on fry or older fish to treat them with an exterior application of salt, which, while not a cure-all, is very efficacious in cases of fungous diseases, and, if prudently used, a safe remedy for fish that have reached the feeding stage.

To apply this remedy to fry in the troughs a saturated solution of salt in water is made—that is, the strongest brine that can be made without heating the water. The flow of water in the trough to be treated is then stopped, which leaves it from 3 to 4 inches deep, when enough brine is poured in to make the water in the trough about as salt as common sea-water, about 1.028 specific gravity. The fish are left in this 20 or 30 minutes, unless they exhibit uneasiness, and then fresh water is turned on. Precaution is taken to dilute the brine with an equal quantity of water, to distribute it the whole length of the trough, actively stirring the water to secure an even mixture; and before turning on the usual water supply a large quantity of fresh water is likewise poured in, distributing it the whole length of the trough and stirring as before, to guard against a too sudden change.

Such precautions are especially necessary in the application of salt to very young fish. A large number of salmon in the sac stage was once destroyed by pouring in a little brine without stirring it; it appeared to sink to the bottom and spread out in a layer by itself among the fry, and all exposed to it died.

ENEMIES OF YOUNG SALMON.

The young salmon are subject to the attacks of many animals and birds, such as the mink, mole, star-nosed mole, common rat, muskrat, kingfisher, great horned owl, great blue heron, sandpiper, and fish-hawk, besides frogs and all large fishes.

At Craig Brook the mink has caused serious loss. As a protection some of the ponds are covered with galvanized poultry netting, and traps are kept constantly set in the avenues by which this animal is apt to approach. The mole burrows through embankments and thus sometimes causes trouble. The star-nosed mole is known to steal dead eggs, and is suspected of taking live ones. The rat sometimes takes young fish from the troughs. The muskrat burrows in embankments and sometimes eats fish.

The different fish-eating birds occasionally steal fish from the ponds or troughs, but if a careful watch is kept the danger is not great. Frogs may be exceedingly destructive to young salmon, and must be caught out of the fish-ponds.

To avoid loss from cannibalism among the fishes it is necessary to feed them well and to take great care that no large fish get in among the small ones.

TAKING SPAWN OF LANDLOCKED SALMON AT GRAND LAKE STREAM, MAINE.

THE LANDLOCKED SALMON.

The landlocked salmon was formerly regarded as specifically distinct from the seagoing form, but it is now generally considered only a variety. The fish found in Sebago Lake and other localities in the United States is known as *Salmo salar sebago*, and the Canadian form as *Salmo salar ouananiche*. From the fish-culturist's point of view, however, the marked difference between the landlocked and the seagoing salmon in habits and growth must separate them as widely as any two species of the same family.

Landlocked salmon are known to exist only in some of the lakes in Sweden, besides the lakes of eastern North America. They are native to most of the lakes of eastern Labrador, including the waters tributary to Ungava Bay, and find their western limit in Lake St. John and vicinity, on the Saguenay River. Those of the latter district have been much written about under the name of "*ouananiche*."

Doubtless the absence of the seagoing instinct is at the bottom of most of the variations from the normal type of *Salmo salar* which the landlocked salmon exhibits. Its lower tone of color, less permanent sexual marks, and greater liability to ovarian disease, as well as different habits of feeding, may perhaps be referable to the same general cause. There are some other peculiarities, however, which are not so easily explained. For instance, the eggs of the landlocked salmon are considerably larger than those of the sea salmon, and the very young fry are correspondingly larger.

The growth of the young of the Sebago landlocked salmon seems to be more rapid than that of the anadromous salmon, for some specimens more than a foot long still bear on their sides dark, transverse bands, characteristic of young salmon; but it may be that the landlocked fish simply retain the marks of the immature stages to a later period of life. This view is supported by the fact that the dark bands are never completely obliterated from the sides of the landlocked salmon, being always very distinct, even in adult specimens, on the under side of the skin, a character absent among migratory salmon.

The landlocked salmon is smaller than the anadromous salmon, but its flesh is fat and rich and of a very delicate flavor. In game qualities it is, for its size, quite the peer of the larger salmon, and affords keen sport to the fly fisherman. It is, therefore, much sought after, and ranks in public favor among the foremost fresh-water species.

The natural range of the landlocked salmon in the United States is much restricted. Leaving out of the question the salmon formerly frequenting the rivers tributary to Lakes Ontario and Champlain, the extent of whose migration is a matter of doubt, we find them only in four limited districts, all in the State of Maine, namely, the Presumpscot River (including Sebago Lake) in Cumberland and Oxford counties, the Sebec River (a tributary of the Penobscot) in Piscataquis County, the Union River in Hancock County, and the St. Croix River in Washington County. There are some minor differences between the fish of these several districts, of which, perhaps, that of size is most notable. The Sebago and Union River fish are much larger on the average than those of the Sebec and St. Croix. The Sebago salmon average at the spawning season 4 or 5 pounds weight for the males and a pound less for the females, while specimens of 12 and 14 pounds weight are not rare, and there is a record of one of 25 pounds. The Union River fish are about the same size. The St. Croix fish vary in the matter of weight in different parts of their range, but the average weight of either sex at Grand Lake Stream is a little less than 3 pounds; specimens of over 6 pounds are rare, and none is on record of over 10 pounds.

After attempts to collect eggs of landlocked salmon in each of the four regions mentioned, it was found that Grand Lake Stream in the St. Croix district afforded excellent facilities for this work. A hatching-station at that place was operated from 1875 to 1892, and has been recently reopened.

The following notes on fish-cultural methods have special application to Grand Lake Stream:

The landlocked salmon of the St. Croix, though originally well distributed through the lakes tributary to that river and still inhabiting a great many of them, finds in some a much more congenial home than in others, its favorite abode being Grand Lake on the Schoodic River. This body of water is of irregular shape, about 12 miles in length and 4 in extreme breadth, fed almost wholly by short streams that form the outlets of other lakes, and from this cause, as well as from the fact that it drains a gravelly country and is girt with clean rocky shores, it is one of the purest of the Maine lakes. Its greatest depth is believed to be little more than 100 feet. Its outlet is Grand Lake Stream, a shallow, rapid, gravelly stream, about 3 miles long, to which the salmon go in October and November to deposit their eggs. Comparatively few of the salmon of this lake resort to the streams tributary to it.

The operations with landlocked salmon necessarily differ from those with migratory salmon. Being at home in fresh water and having there their feeding-grounds, they continue to feed until the close approach of the spawning time, and hence they could not be penned up in the summer without some provision for an artificial supply of food, which would probably involve a great deal of expense and trouble. More-

over, the necessity of collecting breeding fish early in the summer does not exist, because they are at no time more congregated and easy to catch than at the spawning season.

Their capture is easily effected by stretching a net across the outlet of the lake and leading them through a tunnel-formed passage into an inclosure of netting. There happens to be at this point a wide surface of smooth bottom, with water from 1 to 3 feet in depth, affording an excellent site for spacious inclosures, not only for entrapping but for assorting and storing salmon during the spawning season. Nets are generally stretched across the stream (to keep the fish back in the lake) immediately after the beginning of the close season, September 15. The earliest of them begin to spawn before the end of October, but the actual inclosing of the breeding stock is deferred until the early days of November. The taking of spawn generally begins about November 6 and continues two or three weeks. Commonly by November 20 or 22 this work is completed, and the breeders are carried a mile or two up the lake and liberated.

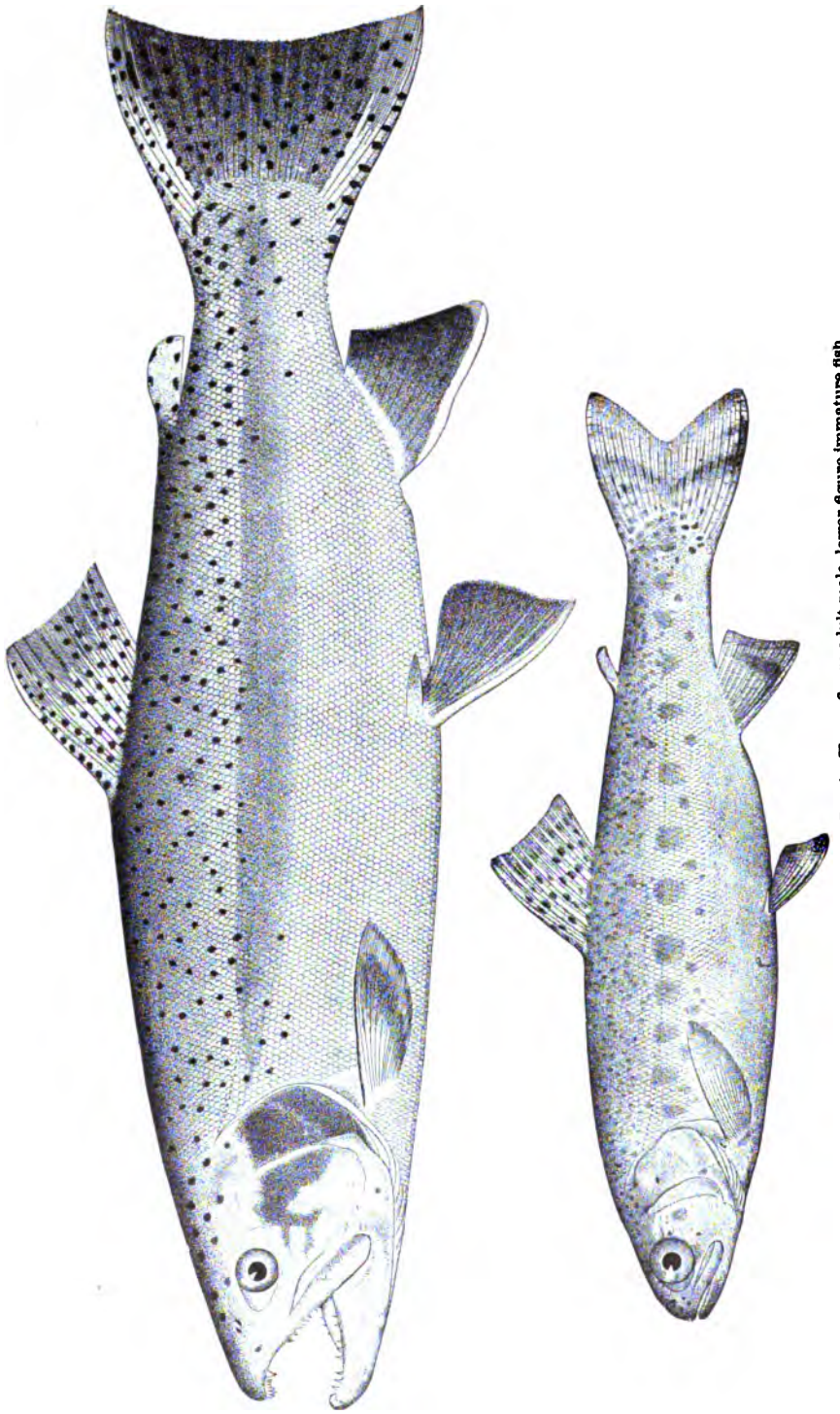
The method of manipulation is the same as at the Craig Brook station, and does not differ materially from that adopted by all the American breeders of *Salmonidæ*. The results in the impregnation of the spawn are not so uniformly satisfactory as with sea salmon. Ovarian disease seems more prevalent among landlocked than among migratory salmon. The occurrence of white eggs among the normally colored and healthy ones, as they are yielded by these fish, is very common, and occasionally the entire litter is defective. It is not improbable that some eggs are incapable of impregnation, though exhibiting no visible signs of disease. However, the general result is satisfactory, the ratio of impregnated eggs being from 93 to 95 per cent.

The facilities for developing and hatching the eggs at Grand Lake Stream are rather poor. No good site could be found by the side of the stream, no suitable brook could be found near enough to the fishing-grounds, and the neighboring springs lacked either volume or facilities for utilization. Of three hatcheries, two use spring water exclusively, and one of them lake or stream water exclusively. The lake water is preferred, but unfortunately it can only be used for the slow development of part of the eggs, circumstances connected with the floating of timber down the stream compelling the evacuation of that hatchery in March. The main hatchery is well located except that the water is from springs, and this unfavorable circumstance is well counterbalanced by the facilities for aeration, which are very good and very fully employed. The eggs are placed upon wire-cloth trays in stacks or tiers, ten deep, and arranged for a free horizontal movement in the water.

The egg shipments are made in January, February, and March, and sometimes in April. The eggs hatched are selected from those that have been retarded in development; the fry reach the age for liberation in June, when their natural food is believed to be abundant.

Experience at Green Lake has supplied some interesting data. Here we find the breeding-grounds of the salmon both in the affluents and in the effluent of the lake, but, unlike Grand Lake, mainly in the affluents. Great Brook, the largest tributary, is most resorted to, and on this stream is located a station for the propagation of this species. The most of the breeders are taken in a trap in the brook, which they readily enter when seeking to ascend to their natural breeding-grounds just above. The trap is constructed of wood, and close to it, also in the bed of the brook, are numerous pens of the same material, in which the fish are assorted and held during the spawning season. On the bank, snug by the pens, is the spawn-house, and a few rods away is the hatchery. The hatchery is supplied with water from Rocky Pond, the source of Great Brook, by a wooden flume 7,050 feet long, supported by wooden trestles, at some points elevated many feet above the ground. In cold weather the water cools off 1¼ degrees in passing down this flume; in warm weather it warms up 1½ degrees. Though the summer temperature during the early years of the station was sometimes over 80° F. and some other species succumbed to the heat, the landlocked salmon endured it safely, and the only notable effect on them was that at 75° and upward the adults reared in the station ponds refused to eat.

As at Grand Lake Stream, among the adult wild salmon caught for breeding each year are many more females than males. In 1889 the proportion was 3 females to 2 males; in 1893 it was 9 to 4. The size of the Green Lake salmon is remarkable; the mean of 69 full-roed females in 1889 was 7.8 pounds in weight and 25.5 inches in length; the males the same year averaged 5 pounds in weight and 22.3 inches in length; one female weighed 11 pounds 9 ounces, and measured 30 inches; another, 11 pounds 6 ounces in weight, was 30½ inches in length; one male, 31 inches long, weighed 13 pounds 8 ounces. The number of eggs yielded by the females is about 4,000 each.



SALMO IRIDEUS. *Rainbow Trout.* Upper figure adult male, lower figure immature fish.

THE RAINBOW TROUT.

DESCRIPTION OF THE FISH.

The body of the rainbow trout (*Salmo irideus*) is comparatively short and deep, and is more elongate in males than in females. The average depth is contained about three and four-fifths times in the body length. The short head, which is obtusely ridged above, is about one-fourth the total length. The mouth is smaller than in other species of *Salmo*, the maxillary reaching scarcely beyond the eye, which is rather large, and is contained five times in the side of the head. The caudal fin is distinctly but not strongly forked. On the vomer are two irregular series of teeth. The dorsal rays number 11 and the anal 10. In the typical species there are about 135 scales in the lateral series, with 20 rows above and 20 below the lateral line; in the several subspecies the number of rows of scales along the side is from 120 to 180. The color is variable, depending on sex, age, and character of water. Typical adult fish are bluish above, silvery on the sides, profusely and irregularly dark-spotted on the back and sides, the spots extending to the vertical fins, with a red lateral band and blotches and a nearly plain belly. The sea-run fish are nearly plain silvery. The chief distinguishing color characteristics of the varieties are in the number and position of the spots.

RANGE AND VARIATION.

The rainbow trout is not indigenous to eastern waters, its original habitat being the Pacific coast of the United States. It is especially abundant in the mountain streams of California. A few specimens, however, have been taken in salt water, and it is not unlikely that some find their way through the rivers into the sea.

The species is subject to considerable variation in form and color in different parts of its range, and the following varieties have received recognition by ichthyologists: The brook trout of western Oregon and Washington (*Salmo irideus masoni*), which rarely weighs as much as a pound and is locally abundant in the streams of the Coast Range from Puget Sound to southern Oregon; the McCloud River trout (*Salmo irideus shasta*), which attains a large size, is abundant in the streams of the Sierra Nevada Mountains from Mount Shasta southward, and is the rainbow trout which has received most attention from fish-culturists; the Kern River trout (*Salmo irideus gilberti*), which attains a weight of 8 pounds and is found only in Kern River, California; the noshee or nissuee trout (*Salmo irideus stonei*), which inhabits the Sacramento basin and reaches a weight of 12 pounds; the golden trout of Mount Whitney (*Salmo irideus aqua-bonita*), which inhabits streams on both sides of Mount Whitney, California.

In the extensive section of the West in which the fish abounds its name varies in different localities; red sides, mountain trout, brook trout, and golden trout, besides rainbow trout, are some of the popular appellations, while in the States east of the Mississippi River it is very generally called rainbow trout or California trout.

TRANSPLANTING.

The rainbow trout has been successfully transplanted in many of the mountain streams in different parts of the United States, where it grows and multiplies rapidly, as is shown by the many favorable reports. The best results, however, seem to have been obtained from plants made in streams of Michigan, Missouri, Arkansas, throughout the Alleghany Mountain ranges, and in Colorado, Nevada, and other Western States. It was introduced into eastern waters by the United States Fish Commission in 1880, but it is possible that specimens of it, or its spawn, had been brought east prior to that time by some of the State commissions or by private enterprise.

It is believed that this species will serve for stocking streams formerly inhabited by the brook trout (*Salvelinus fontinalis*), in which the latter no longer thrives, owing to the clearing of the lands at the sources of the streams, which has produced changed conditions in and along the waters not agreeable to the brook trout's wild nature. The rainbow is adapted to warmer and deeper waters, and is therefore suited to many of the now depleted streams which flow from the mountains through the cultivated lands of the valleys.

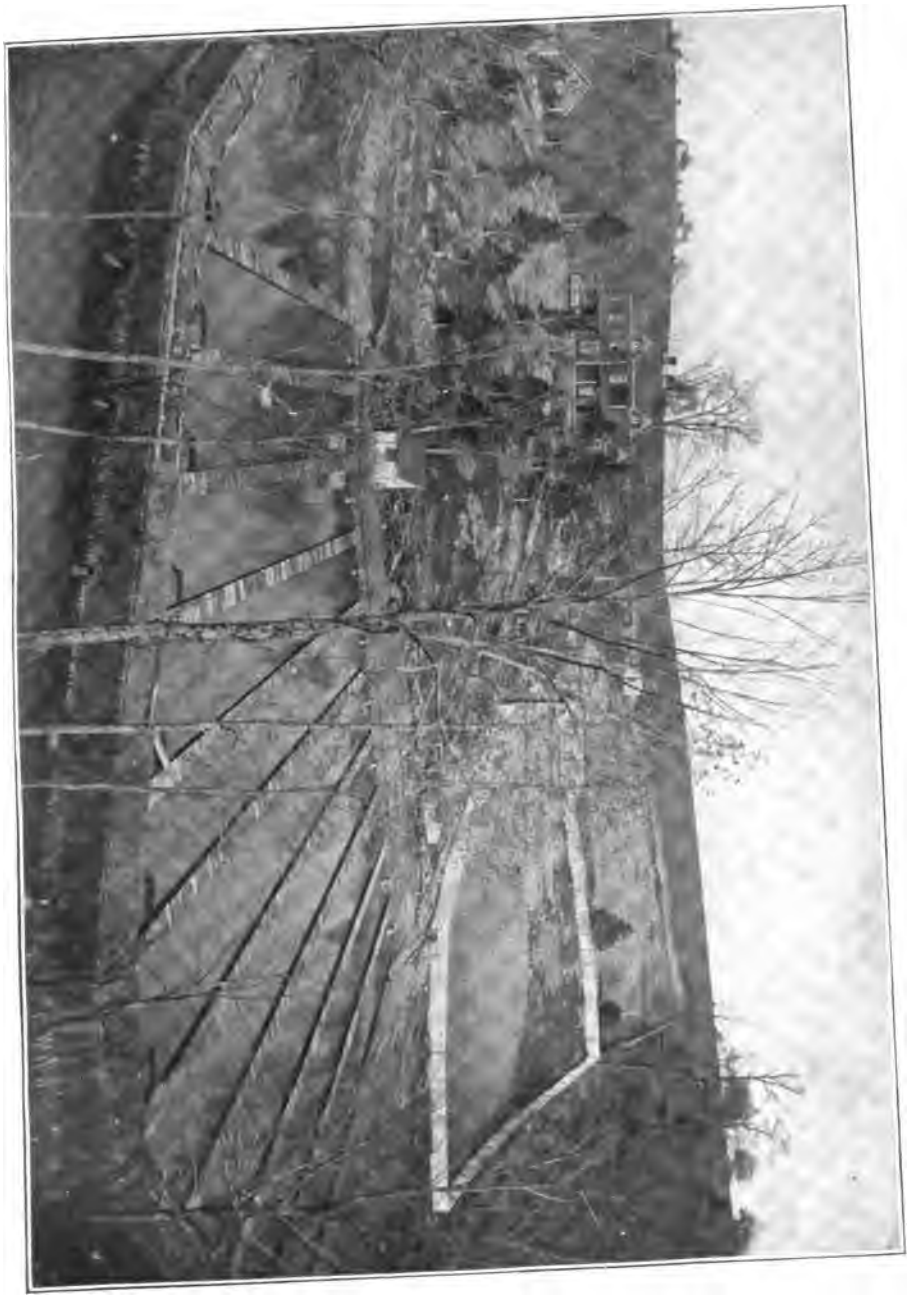
Rainbow trout differ widely from brook trout and other pugnacious fishes, in that they feed principally upon worms, larvæ, crustacea, and the like, and do not take readily to minnows as food. They should be planted in spring or early summer, when their natural food is abundant, as they will then grow more rapidly and become accustomed to life in the stream, and when worms, larvae, etc., are no longer to be found, their experience and size will enable them to take a minnow or anything that may present itself in the shape of food.

Fry should not be planted in open waters until they are several months old, and then not until the temperature of the streams begins to rise; but fish hatched in December and January can safely be planted in April and May.

SIZE AND GROWTH.

The size of the rainbow trout depends upon its surroundings, the volume and temperature of the water, and the amount of food it contains. The average weight of those caught from streams in the East is probably less than a pound, but some weighing 6¾ pounds have been taken. In the Ozark region of Missouri they are caught weighing 5 to 10 pounds. In some of the cold mountain streams of Colorado their average weight is not more than 6 or 8 ounces, but in lakes in the same State, where the water becomes moderately warm in summer and food is plentiful, they reach 12 or 13 pounds, fish of this size being from 25 to 28 inches long. In the Au Sable River, in Michigan, they

PLATE 20.



WYTHEVILLE STATION, VIRGINIA—NEW REARING-PONDS.

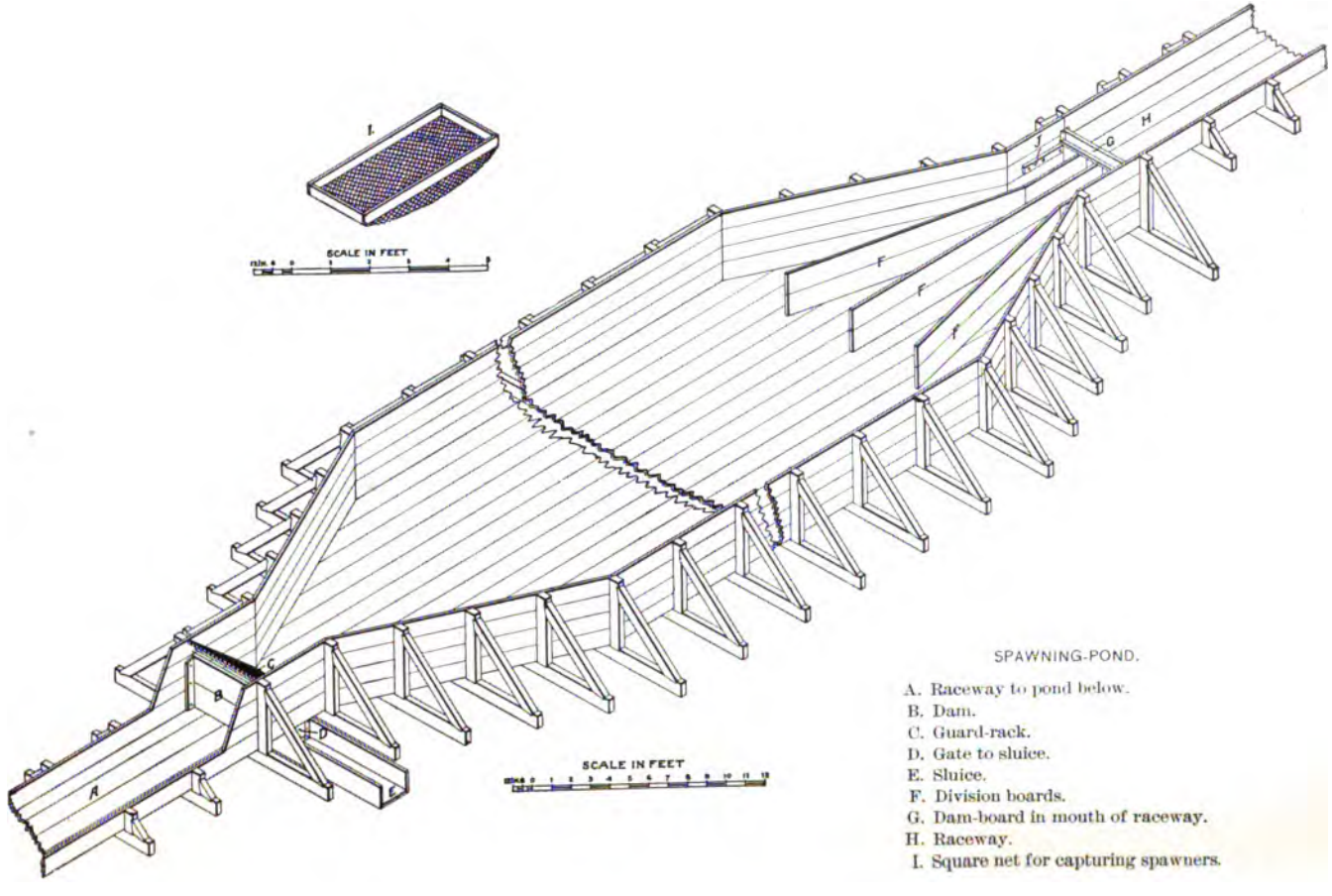
A guard-rack made of thin, narrow slats is arranged on an incline of about 45°, as shown at C. If the water is to be used again in ponds below, a receiver is built underneath the bottom of the pond at the lower end, between the foot of the guard-rack and the dam-boards, and the floor of the pond immediately over the receiver is cut away and fitted with a grating. This allows matter to fall through the receiver and from there it is washed through the sluiceway, which taps the receiver by drawing the gate shown at D. The sluiceway, E, is covered and leads off to a general waste-ditch.

The pond is provided with a spawning-race about a foot deep, 4 feet wide, and 25 feet long, placed at the upper end of the pond, as shown at H. Three division boards (shown at F), about 12 feet long and of suitable width to come within 1 or 2 inches of the surface of the water when the pond is filled, are firmly fixed at the bottom. The object of these boards is to form four avenues leading to the raceway, so that one or two pugnacious fish can not command the approach and keep back spawning fish inclined to enter. There is a dam across the raceway about 4 inches high (shown at G) for the purpose of bringing the water to that depth in the lower end, so that when the trout enter they will find sufficient water in which to swim freely, and not be inclined through fear to return to the pond.

The water in the pond is of sufficient depth to bring its surface within 6 inches of the top of the dam in the raceway, which will give the fish, in entering the raceway, a jump of 7 inches, allowing 1 inch for the depth of water on the dam in the raceway. This distance has been found more satisfactory than any other, and spawning fish alone will go up. If a jump of less than 7 inches is given, other fish can enter the raceway without much exertion, and will ascend and disturb the breeding fish, which, when spawning, should be kept strictly by themselves.

There is no rule regarding the supply of water that applies to a spawning-pond at all times and in all places. It is necessarily governed by the temperature of the water, size and shape of the pond, size of the fish to be supported, the amount of shade, etc. For a pond such as has been described, where water is plentiful, at least 200 gallons per minute should be provided, with not less than 75 gallons per minute as a minimum, even where the temperature is from 50 to 55 degrees and all other conditions are favorable. While the former amount is not absolutely necessary for the support of the fish, it insures the pond being kept clean and the fish are more inclined to enter the raceway at spawning time. In order to maintain an even temperature in the pond the earth is banked against the sides and ends, covering the framework shown on plate 21, and the embankments are made broad enough on top to admit of a good footway around the ponds.

Such a pond as this can accommodate from 1,000 to 1,500 breeding fish. Fish must not be overcrowded, and in estimating the capacity of



SPAWNING-POND.

A. Raceway to pond below.
B. Dam.
C. Guard-rack.
D. Gate to sluice.
E. Sluice.
F. Division boards.
G. Dam-board in mouth of raceway.
H. Raceway.
I. Square net for capturing spawners.

a pond several modifying conditions must be considered, such as the size of the fish, water supply, temperature, and shade. In stocking the spawning-pond a good proportion is two females to one male. The breeding stock is selected carefully every year; only sound and perfect fish are retained for the next season, and the blind and emaciated fish of both sexes are destroyed.

TAKING THE SPAWN.

The spawning season varies with the locality and the temperature of the water. It is usually two to four weeks later in the streams than where the fish are kept confined in spring water. In the ponds at Wytheville the spawning fish may be found any time after the 1st of November; the season is well started by November 15, and generally closes about the 1st of March. December and January are the best months. In California the season extends from the 1st of February to May, and in Colorado begins early in May and continues until July.

The natural nests of these fish are made on gravelly bottoms, and are round or elongated depressions about the size of a dinner plate. After the eggs have been deposited and fertilized they drop between the pebbles of the nest, where they lie protected until hatched.

Where spawning-ponds are provided with suitable raceways the fish will ascend from the ponds into them, seeking a place to make their nests, and may then be taken out and stripped of their spawn. To take the fish from the raceway, a square net (I, plate 21) is dropped in on the cleats nailed against the side walls in the approach, shown at J, the dam in the mouth of the raceway is raised, and the fish driven back into the net. The net is then lifted out of the water, and if it contains too many fish to handle conveniently a landing-net is used to take out part of them before the square net is moved. The ripe fish are then placed in tubs or other vessels provided for the purpose. If too many fish are put in the tub at one time they become restless and sick before they can be stripped of their spawn.

There are two methods of taking and impregnating the spawn of fishes, the "wet" and the "dry" methods. By the "wet" method the eggs are taken in a pan containing sufficient water to cover them and allow them to mix freely with the milt, which is immediately added. After the contents of the pan have been stirred for a few seconds with a feather, the eggs are set aside and left undisturbed during fertilization. The "dry" or "Russian" method is now in general use; the eggs and milt are taken in a moist pan and it makes little difference which is taken first, but one should immediately follow the other, and the contents of the pan be thoroughly mixed.

After the eggs and milt have had time for contact, and before the eggs begin to adhere to the bottom of the pan, water is added to the depth of about an inch, the eggs being kept in gentle motion, by turning the pan, to prevent adhesion. After 2 or 3 minutes the milt

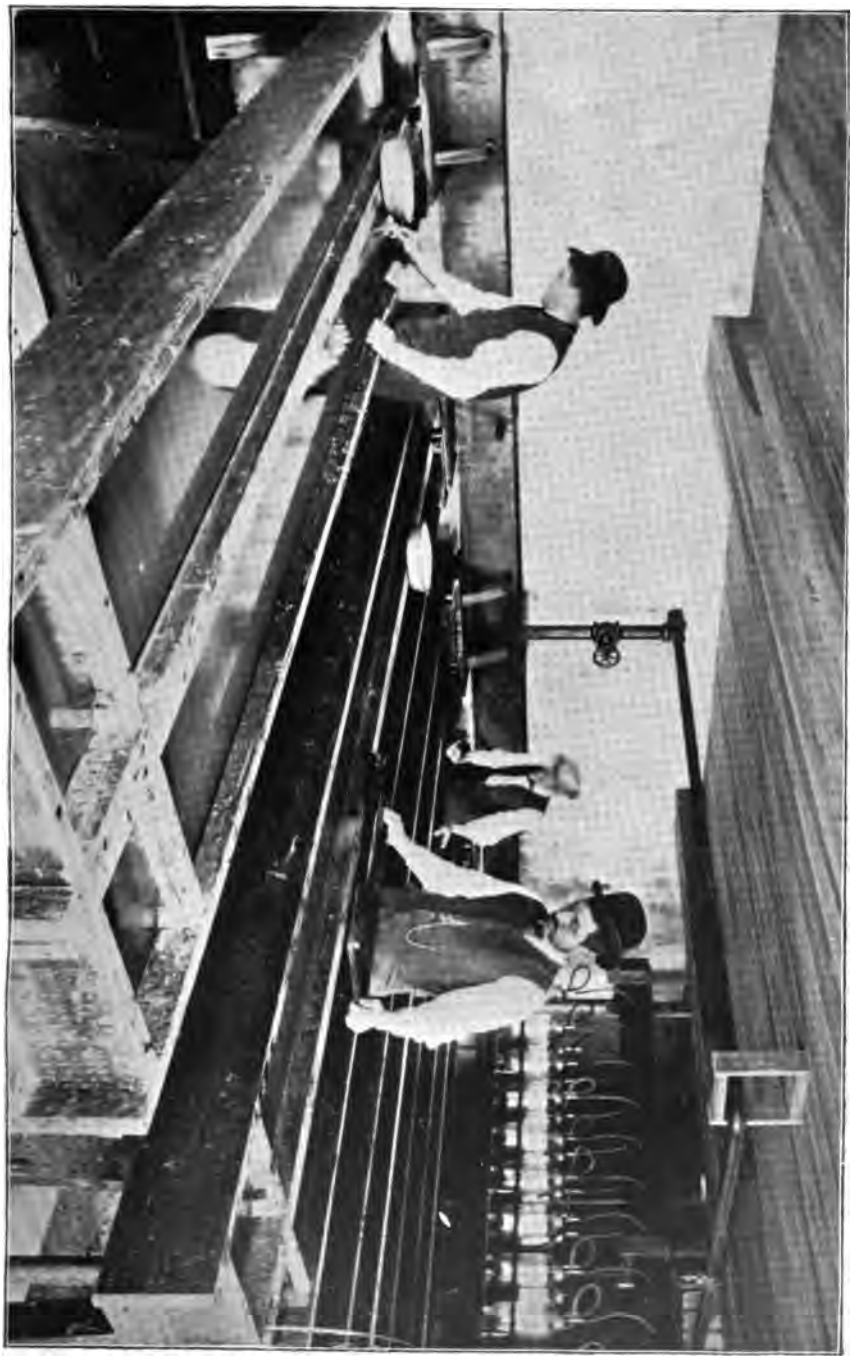
is poured off and clear water is put in the pan, in which the eggs are allowed to remain until they separate, which will be in from 15 to 45 minutes, depending on the temperature of the water. It is preferable to take the eggs to the hatchery before the milt and water are poured off, and there rinse them off and place them directly on the hatching-trays (previously arranged in the troughs) and then allow them to separate. In freezing weather it is advisable to strip the eggs in water or to use two pans, one set in the other, with water in the bottom pan to prevent the eggs from being chilled.

In taking spawn the manipulation of the fish without injury is a very delicate and exacting task, full knowledge of which can only be acquired by experience, as it is difficult to squeeze the spawn from the fish without injuring or even killing it. In taking hold of the fish in the spawning-tub the operator catches it by the head with the right hand, the back of the hand being up, and at the same time slips the left hand under the fish and grasps it near the tail, between the anal and caudal fins. A fish caught in this way can be easily turned over as it is brought out of the water, so that its abdomen is up and in the proper position for spawning by the time the spawning-pan is reached. If the fish struggles it must be held firmly, but gently, until it becomes quiet, and when held in the right position it will struggle only for a moment. A large fish may be held with its head under the right arm.

When the struggle is over the right hand is passed down the abdomen of the fish until a point midway between the pectoral and ventral fins is reached, then with the thumb and index finger the abdomen is pressed gently, and at the same time the hand is slipped toward the vent. If the eggs are ready to be taken they will come freely and easily, and if they do not, the fish is put back in the pond until ready to spawn. If the eggs come freely from the first pressure the operation is repeated, beginning at or near the ventral fin.

After the first pressure has been given, by holding the head of the fish higher than the tail, all of the eggs that have fallen from the ovaries and are ready to be expressed will fall into the abdomen, near the vent, so that it will not be necessary to press the fish again over its vital parts, the eggs having left that portion of the body. All of the eggs that have fallen into the abdomen below the ventral fin can be easily ejected without danger of injury to the fish, caused by unnecessary pressure over its important organs after the eggs have left that part of the body. If these directions are judiciously and carefully followed but little, if any, damage will result; and, as an illustration, it may be mentioned that fish have been kept for 14 years and their full quota of eggs extracted each season during the egg-producing term, which is normally from 10 to 12 years. The male fish is to be treated very much in the same manner as the female, except the milt must not be forced out, only that which comes freely being taken.

After stripping, the fish are not returned to the spawning-pond, but spent females are placed in one pond and the males in another. The



INTERIOR VIEW OF WYTHEVILLE HATCHERY, SHOWING MEN PICKING OUT DEAD EGGS.

males are very pugnacious at this season, and sometimes fight for an hour or more at a time, until they are entirely exhausted; they run at each other with open mouths, lock their jaws together, and in that position sink to the bottom of the pond, where they lie for a short time, each holding the other in his grasp until rested, when they rise and resume the combat. As their teeth are abnormally long, they scar each other and even bite pieces of skin and flesh from the sides of their antagonists.

The males are good breeders at two years old, but very few females produce eggs until the third season, when they are from 30 to 36 months old. At Wytheville hatchery about 1 per cent of the females spawn at 2 years of age; about 50 per cent at 3 years, and about 85 per cent each season after that. About 15 per cent of the fully matured females are barren each season. It was at one time thought that the same individuals were barren each year, but experience has shown that such is not the case, as fish which were barren one season have been held over, in a separate pond, until the following year, when a large portion, if not all, produced eggs. This sterility may be the result of injuries which were received the previous season, during the progress of spawning.

EGGS.

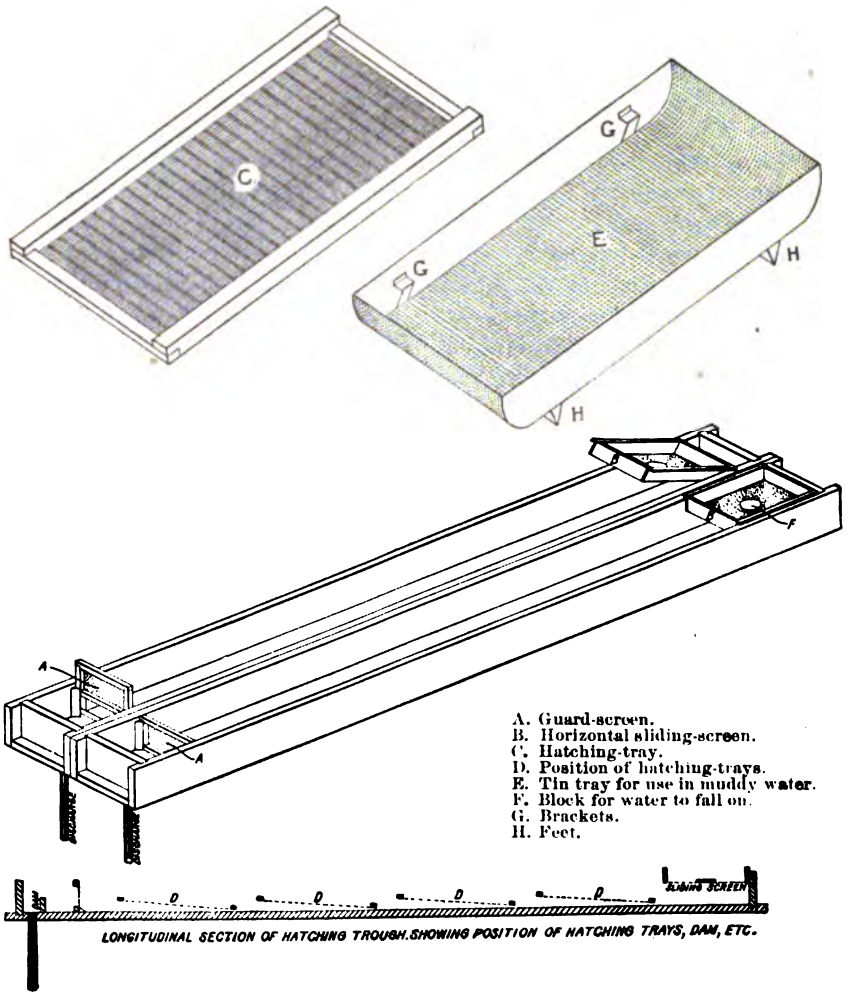
The number of eggs produced in a single season depends upon the size and age of the fish. The maximum from one 3 years old, weighing ½ to 1½ pounds, is from 500 to 800; from one 6 years old, weighing 2 to 4 pounds, it is 2,500 to 3,000. The eggs vary in size from 4½ to 5 eggs to the linear inch, and are of a rich cream color when first taken, changing to a pink or flesh color before hatching.

THE HATCHING-TROUGHS AND TRAYS.

The eggs are incubated on trays placed in troughs of various sizes and shapes, which at Wytheville are set in pairs, as shown on page 68. They are made of the best pine lumber, dressed to 1½ inches thick, and are 15 feet long, 14 inches wide, and 8 inches deep. Fourteen inches from the lower end inside is a guard-screen of perforated tin or wire mesh, fastened on a frame exactly fitted across the trough. Tin with perforations of $\frac{1}{16}$ inch for very young fry, and larger ones as the fish grow, is preferable to wire. The screen is arranged to slide vertically between beveled cleats, that it may be kept clean easier. A plain board, 3¼ inches wide, is placed 4 or 5 inches from the lower end of the trough to serve as a dam.

In the upper end of the trough horizontal screens (B, page 68), made of perforated tin, are used. These are so constructed that they can be slipped forward or raised up (as shown in the illustration) in feeding the fry or cleaning the troughs, and the water falling on a small wooden block in the center of the screen is thoroughly aerated before entering the trough. This arrangement possesses many advantages over the old method, where the screens were vertical, or nearly so, as it permits the

fish to ascend to the head of the trough and receive the water as it falls from the screen, which is very beneficial. Its use not only keeps the fry clean even in muddy water, but also reduces the loss of fry from suffocation in the early stages, caused by their banking around the vertical screens, and obviates the necessity for trough covers to prevent jumping, as trout rarely jump where the horizontal screen has been adopted.



Hatching-troughs, Guard-screen, etc.

Hatching-trays (C), made about twice as long as wide, i. e., 28 by 13½, are convenient to handle and adjust in the troughs. The sides of the frame are made of good pine lumber, dressed, 1 inch square; the ends are dressed ½ by 1 inch, and are cut into the sides to form a smooth surface on the bottom for the wire filling. The wire used on the trays is woven with 8 threads to the inch, with a mesh ⅞ inch long, and should be well galvanized after it is woven, in order to prevent rusting at the laps.

Four hatching-trays are placed in each trough and are secured by keys or wedges, and should be from 1 to 2 inches lower at the end next to the head of the trough, as shown at D, D, D, D, page 68. If placed in this way, each tray will hold from 12,000 to 15,000 eggs with safety. Muddy water during the hatching season necessitates the use of a tin tray with a perforated bottom (shown at E, page 68), which is 13¾ inches wide and 32 inches long. This sets inside of the hatching-trough on feet raising it an inch above the bottom of the trough. The hatching-tray containing the eggs is placed inside and rests on the brackets shown at G. The fish, as they hatch out, fall from the hatching-tray upon the perforated bottom of the tin tray, and by their movements work the sediment through, leaving them on a clean bottom and in no danger of being smothered. The tin trays are also useful in counting fish, or in holding small lots of fish of different species in the same trough. Where supplementary trays are not used, the fry fall directly into the troughs.

Troughs 15 feet long will admit of four hatching-trays in a single row, each of which will safely carry 12,500 eggs, making 50,000 to a trough; this is enough to work easily, but if it is necessary to make more room a double row of trays may be put in, one tray resting on the top of the other. Thus the trough could contain 100,000 eggs as its full capacity. The troughs will carry this number up to the time of hatching by placing the trays lower at one end than the other, as previously described.

When the hatching stage arrives, two trays of 12,500 eggs each are as many as should be left in one trough; with this number, by using the horizontal sliding-screen in the upper end, there is but little danger of the alevins congregating and smothering in any part of the trough. If it is necessary to hatch a much larger number than this in one trough, the sliding-screen is so arranged that the water falls well up against the end of the trough. This is done by raising the screen and turning it back against the reservoir, or by putting in a wedge-shaped block for the water to fall upon, turning the thin side of the block toward the upper end of the trough. Fifty thousand trout have been hatched in one trough prepared in this way without loss from suffocation, but it is not advisable to hatch such a large number together.

The amount of water necessary for hatching and rearing depends upon the temperature and the manner in which the water is applied. The water should receive as much aeration as possible before entering the compartments containing the fish and eggs. At Wytheville, where there is an even temperature of water of 53° in the hatchery, about the following quantities are used in the troughs containing fish and eggs:

100,000 eggs during incubation, 12½ gallons per minute.
100,000 fish hatching to time of feeding, 30 gallons per minute.
100,000 fish from 1 to 4 months old, 50 gallons per minute.
100,000 fish 4 to 6 months old, 100 gallons per minute.
100,000 fish from 6 to 12 months old, 200 gallons per minute.

These amounts are ample, and probably even half would suffice if it were necessary to economize in the use of water. In rearing-ponds more water is required, as the circulation is not so good and the out-door exposure causes the temperature to rise. If water is plentiful, double the amounts stated would be advisable for pond-culture.

During the last two seasons at Wytheville 80 to 85 per cent of the eggs taken produced fish, of which about 70 per cent were raised to three months old and 55 per cent to yearling fish. The loss in eggs was almost entirely due to failure in impregnation, very few being lost from other causes.

CARE OF EGGS AND FRY.

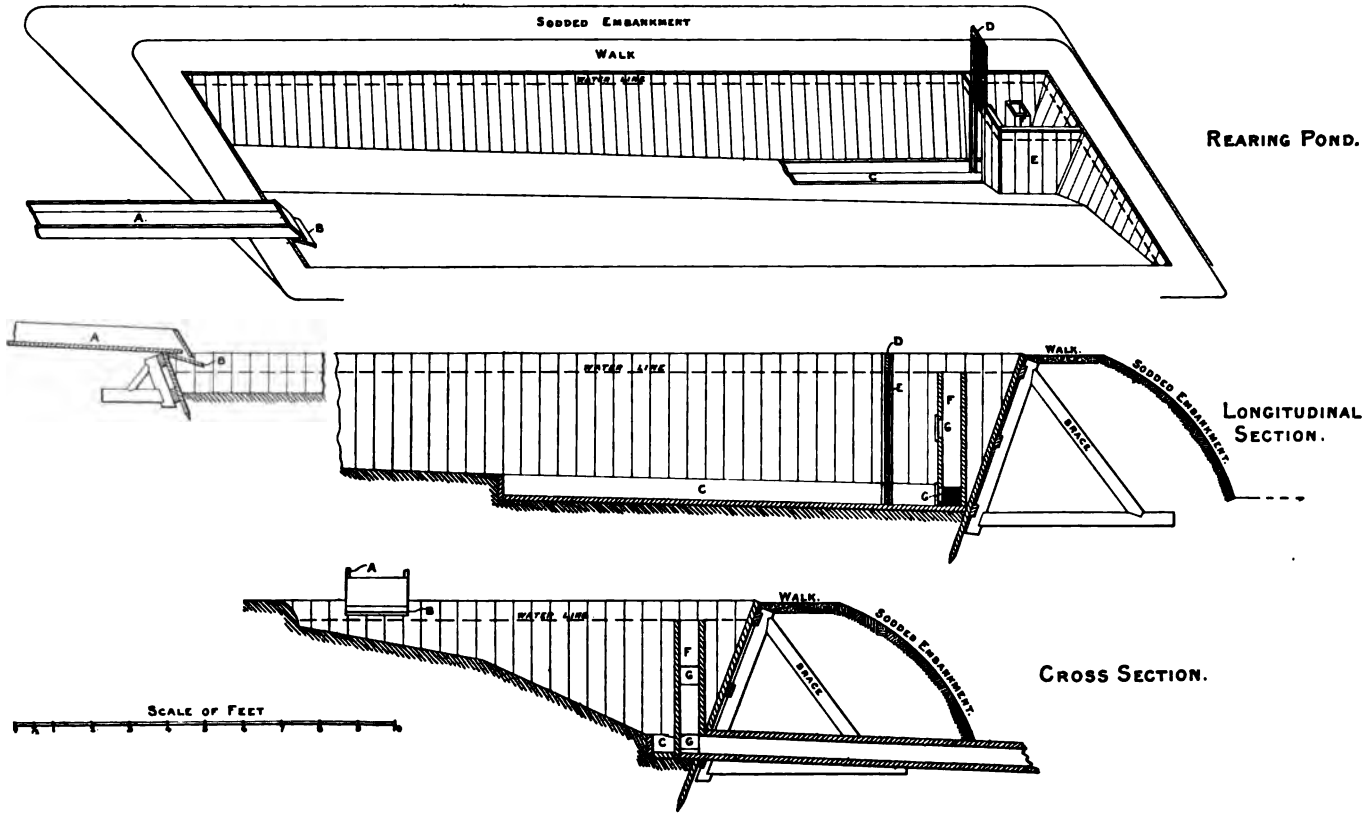
After the eggs are placed on the trays, the only attention necessary until the hatching begins is to keep them clean; the dead eggs, which may be known by their turning white, must be picked out at least once each day. After the eye-spot can be plainly seen it is well to run a feather through the eggs for the purpose of changing their position on the trays, and to disclose any foreign matter or dead eggs that may be hidden underneath. The greatest care should be exercised in handling the eggs at any time, particularly from the first or second day after collection up to the appearance of the eye-spot, and then only when absolutely necessary. During this period, the eggs are very delicate, and even passing a feather among them may cause a heavy loss.

The time required for hatching depends mainly upon the temperature of the water. Rainbow trout eggs will hatch in water at 50° in from 42 to 45 days, each degree colder taking 5 days longer, and each degree warmer 5 days less; the difference increases as the temperature falls and diminishes as it rises.

After the fry hatch they require but little attention until the umbilical sac is absorbed and the time for feeding arrives. They are examined each day, and the dead fish and decayed matter removed from the troughs, which are kept perfectly clean, and if possible provided with a thin layer of coarse white sand on the bottom, to keep the fish in healthy condition. As the fish grow they should be thinned out in the troughs, from time to time, as their size may require. When they first begin to feed, 12,000 to 15,000 fish to the trough are not too many; but by the time they get to be 1¼ to 1½ inches long they must be divided into lots of 8,000 to 10,000 to each trough; while with fish averaging 3 inches in length, 3,000 to 4,000 are as many as one trough will accommodate. It is advisable to give as much room as is practicable.

REARING-PONDS.

Ponds for rearing trout are from 8 to 12 feet wide, and of any desired length up to 60 feet, which, for convenience in drawing them off and in feeding the fish, is about the extreme limit. The size, shape, and arrangement of the ponds must depend upon the ground on which they are to be constructed. If practicable, it is best to build them on a



REARING POND.

A. Supply-trough.
B. Apron.
C. Receiving-trough.
D. Guard-screen.
E. Crib around standpipe.
F. Standpipe.
G. Holes in standpipe.

hillside, one above the other, with earth and piling embankments on the lower sides and at the ends. A pond of this kind is shown in plate 23, and is the one here described. Various materials may be used for damming the water. The embankments may be made altogether of earth or lined with stone, brick, cement, or timber, according to circumstances. Where the ground is of a porous or loose formation it is necessary to use piling or cement for the inside of the embankments and possibly cement for the bottoms, but earth bottoms are best where the nature of the ground permits. The water enters the pond at one end and discharges from the lowest opposite corner. The bottom is graded as shown in the cross-section, plate 23, with a slope toward the outlet, so that when all the water is drawn out the fish are led into the receiving-trough (C), the top of which is flush with the earth bottom in that part of the pond.

The outlet for the water is an L-shaped pipe, shown at F, and is placed in the corner of the pond, the long end passing through the piling and underneath the pond embankment; the short end, called the standpipe, stands close to the inside corner of the pond, in an upright position. The standpipe has two or more holes cut through (G) on the side next to the receiving-trough, to let the water pass out in drawing down the pond. The size of these holes is in proportion to the size of the standpipe, which, in turn, is governed by the size of the pond. The holes may have blocks of suitable size tacked over them to allow the pond to fill with water, or, what is more convenient, covered with blocks arranged to slip down in grooves, one block resting on the other. Surrounding the standpipe is a crib, the front of which is 15 inches or more from the pipe and contains an opening for a guard-screen, which is 14 to 16 inches wide and made with copper or galvanized wire cloth, the size of the mesh depending on the size of the fish in the pond. In the bottom of the pond is a receiving-trough (C) for the fish, built in proportion to the size of the pond; 10 feet long, 16 inches wide, and 6 inches deep is a satisfactory size for a pond like the one described. This trough extends to and connects with the standpipe, and the guard-screen is arranged to fit down on the inside. Every part is made secure, to prevent fish from escaping when drawing off the water. The supply-trough or pipe is arranged to keep the fish from jumping into it from the pond, as shown at A.

STOCKING THE REARING-PONDS.

The rearing-ponds at Wytheville are stocked gradually, 500 to 1,000 fish being placed in the pond and trained to take food before more are added, as that number can generally find enough natural food to subsist upon until they learn to take artificial food. When they have been accustomed to hand-feeding another 1,000 fish are added, and in about ten days 2,000 more, this practice being continued until the pond is stocked with the desired number. When fish are first released in ponds

they are wild and run away from the food given them; hence the necessity of teaching a few fish to eat before more are added. The number of fish that a pond of a given size can support depends upon the amount of water and shade and the temperature of the former. Ten thousand fish are ample for a pond 10 by 50 feet, with water deepening from 3 inches to 3 feet.

FOOD FOR FRY.

Beef or sheep liver, ground or chopped to a pulp, seems to be the most satisfactory artificial food for young trout. Fresh, hard-boiled eggs, grated fine, are good, but expensive. Efforts have been made to produce a natural or living food, such as insect larvæ and small crustaceans, and this may yet be accomplished for late spring and summer feeding, but for feeding the fry during the first three or four months of their lives, which is in the winter season, there is nothing better than liver. Shad and herring roe, put up in sealed tin cans, have been used to a limited extent with satisfactory results, and it is believed that they will furnish a wholesome and natural diet.

The manner of feeding young fry is very important, as the losses from improper feeding are greater than from all other causes combined. If there is undue haste the water becomes polluted, or the food is so distributed that some fish are prevented from getting their proper share. Polluted water is very injurious to the young fish, being apt to produce inflammation of the gills and a slimy, itching condition of the skin, which often causes heavy mortality.

The fry are ready to take food as soon as the sac is absorbed, the time required for this depending upon the growth of the fish, which is governed by the temperature of the water. Where the temperature is regular at 53° they will take food in about 30 days after hatching, and the time to commence feeding may be closely determined by watching the movements of the fish. Before the sac is entirely absorbed they will begin to break up the school on the bottom of the trough and scatter through the water, rising higher and higher from the bottom each day, until they can balance themselves gracefully in a horizontal position, all heading against the current and swimming well up in the water. By dropping some small bits of cork or the nap from red flannel on the surface of the water it can be determined if they are ready for food; if they strike at the pieces as the current carries them down it is evident they are hungry.

The liver is prepared by chopping it very fine and, if necessary, mixing it with water, in order that it may be distributed evenly. It should be given to the fish by dipping a feather into the liver and gently skimming it over the surface of the water. After the fish grow to be 1¼ to 1½ inches long they begin to take up the food that settles on the bottom of the trough; it is then not necessary to mix the food with water, and it can be given by hand. The young fry are fed five or six times a day and the food given slowly and sparingly. After they

WYTHEVILLE STATION, VIRGINIA—SPAWNING-POND, SHOWING RACEWAY.

learn to take their food from the bottom of the trough it is necessary to feed them only three times daily, but more food must be given at each meal.

FOOD OF ADULT FISH AND YEARLINGS.

In domestication the rainbow trout is preferably fed upon a meat diet altogether, if it can be had plentifully and sufficiently cheap; otherwise a mixture of liver and mush may be used advantageously. The mush is made by stirring wheat shorts or middlings in boiling water until the mixture becomes thick; it will keep for several days, even in warm weather, if put in a cool place. The liver is ground or chopped fine and mixed thoroughly with the mush in any desired proportion up to four-fifths of the whole, but it is better to mix only as needed. This mixture has been used satisfactorily for many years.

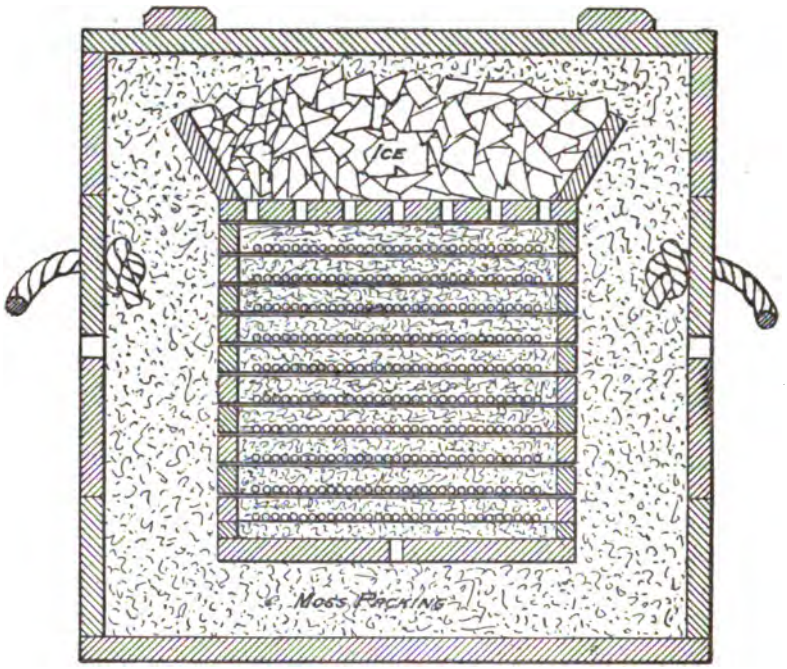
A meat-chopper may be obtained for grinding liver which will do the work in an excellent manner, leaving no strings or gristly chunks to choke the fish. There are several sizes of the machine made, with extra perforated plates having different-sized holes, from one-twelfth to one-fourth of an inch in diameter, so that the meat may be prepared coarse or fine, to suit the size of the fish to be fed. For small fry it is necessary to use the plate having the smallest holes and to grind the food over several times until fine enough to use.

The practice of throwing food into the pond in handfuls causes the fish to come together in great numbers and in a violent manner; and struggling with open mouths to get a bite of the food, they often hurt each other, injure one another's eyes, sometimes even plucking them from the sockets. This is probably one of the main causes of blindness among pond-fed fish.

The most approved method of feeding is to walk along the pond its entire length to the upper end (the fish will soon learn to follow to that point), then scatter a handful of food along the surface of the pond so that it will fall to pieces. The fish follow and take up what has been thrown out and then return to watch for the next handful, and the operation is repeated until sufficient food is given. This manner of feeding induces all the fish to head in the same direction while eating, thus reducing the danger of injury.

The amount of food for a given number of trout depends upon the size of the fish and the temperature of the water, as fish will not take food as freely in water of a low temperature as in warmer water. With water from 50° to 60° a daily ration for 1,000 yearling fish ranging from 3 to 5 inches in length is about ¾ of a pound; while for the same number, 8 to 12 inches long, about 12 pounds per day are required.

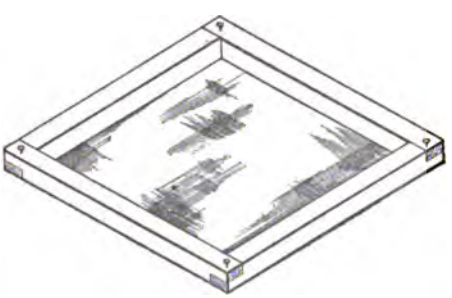
As the fish increase in size the amount of food should be increased proportionately. They are fed twice a day at regular hours, morning and evening, giving half of the daily allowance each time. This keeps them in a thrifty and growing condition.



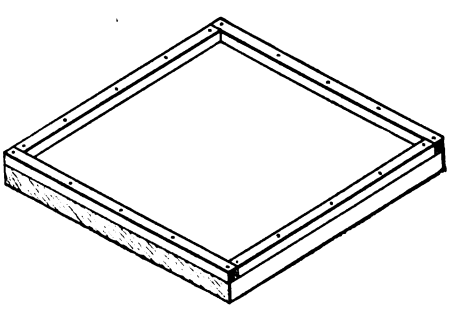
Cross-section through Box after it has been packed and closed.

PACKING EGGS FOR SHIPMENT.

In packing trout eggs for shipment they are usually placed on trays and packed in wet moss and the eggs divided into from five to ten equal parts, according to the size of the shipment, using trays of suitable size to hold each part. If 30,000 eggs are to be shipped, ten trays are used large enough to contain 3,000 eggs each; if 15,000 eggs, ten trays



A. Egg-tray.

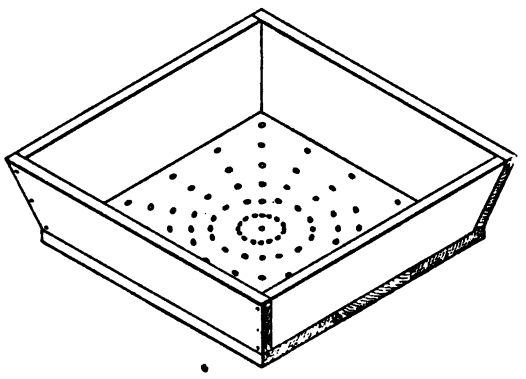


B. Foundation-board.

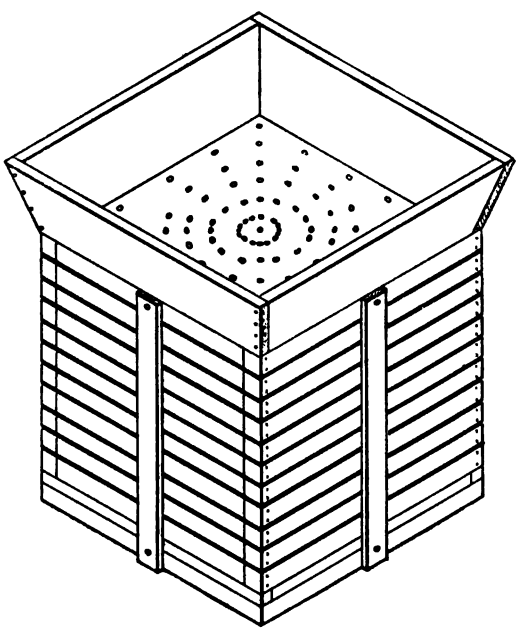
containing 1,500 eggs each; 10,000 eggs, eight trays of 1,250 each, etc., and if over 30,000 eggs are to be shipped the shipment is made in more than one lot. In a package of more than ten trays, especially if the trays are large, the eggs on the lower trays are liable to be crushed

by the weight above, and if less than five trays are used in a shipment the package is liable to become dry, and the eggs reach their destination either dead or in a shriveled condition.

The frames of the trays are made of light, soft wood dressed to $\frac{5}{8}$ by $\frac{7}{8}$ of an inch, with a soft canton-flannel bottom tightly stretched and well tacked on. The trays are made large enough to contain their proportion of the eggs, with an allowance of $\frac{3}{4}$ of an inch between the eggs and the frame of the tray. A foundation-board (B) is made with the same outside dimensions as the tray, with a strip nailed around the edge on the upper side to form a cushion of moss for the bottom tray. A hopper for ice (C) is used on the top tray. The outside case (E) is made 7 to 8 inches larger on the sides (inside measure) and 5 inches deeper than the outside dimensions of all the trays after they are cleated together, including the hopper and the foundation-board, as shown at D.



C. Ice-hopper.



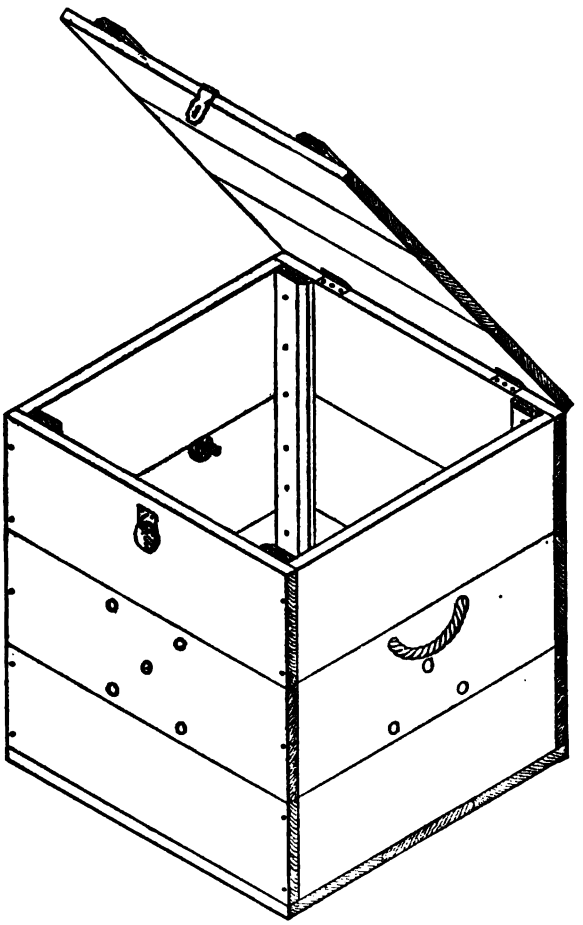
D. Egg-trays packed and cleated.

The trays having been prepared, the eggs are selected, those being taken which show eye-spots and are not too old to reach their destination before the time for hatching. Allowance is made for changes in temperature on the road which would cause them to hatch too soon.

The eggs are taken from the hatching-trays in pans, well cleaned of all sediment, and given a slight concussion by allowing water to fall on them from a small spout or sprinkling pot, which causes the dead and unfertilized eggs to turn white, when they are carefully removed. The

eggs are then accurately weighed or measured (1 ounce may be weighed and counted, or the eggs for one tray counted and then weighed) and the required number placed in a single layer in the middle of the tray, leaving an empty space all round next to the frame.

The trays are then placed one above the other on the foundation-board, after each is covered with a piece of mosquito netting, which should be at least 2 inches larger each way than the tray, and the



E. Outside case.

tray is filled with wet moss, the part immediately over the eggs in a loose manner, the empty space around the eggs packed tight. This gives support to the next tray above and prevents the eggs from coming in contact with the wood and becoming dry and shriveled.

After all the trays are thus arranged the hopper is placed on top and the whole cleated together, as shown at D. They are then ready to be placed in the box or outside case (E). Dry sphagnum moss is placed

in the bottom of the box to a depth of about 3 inches and the crate of trays placed as near the center of the box as possible. The sides are well packed to hold it firmly in position, and when the top of the hopper is reached with the packing it is well filled with ice, the remaining space in the box being filled with moss. Wet moss or wet packing of any kind should never be used for the cushion around the egg-crate, as it does not preserve an even temperature and is liable to freeze solid if exposed to a low temperature in transit. A cross-section of the box thus packed is shown on page 74.

The box containing the eggs should be provided with handles to facilitate moving during transportation, in order that the liability to injury from jarring or concussion may be reduced. For a long journey the lid of the box is provided with hinges and hasp and staple, so that the ice may be easily renewed. Eggs packed as described above have been shipped with safety to all parts of the United States and to foreign countries.

DISEASES OF FRY AND ADULTS.

The most common diseases of trout fry are the inflammation of their gills and a slimy skin disease, which may be caused by impure water; the food itself may produce it, especially if stale liver is used, but it generally follows fouling of the water while feeding. By watching the movements of the fish, the symptoms of disease can generally be detected before it reaches an alarming stage. If the gills are affected the fish will usually swim high in the water in an uneasy, restless manner, as if gasping for breath, and when this is observed the gills must be examined to see if they are becoming inflamed and swollen. If a skin disease is attacking the fish, they generally indicate it by rubbing themselves on the bottom of the trough or against anything that may be convenient, or by diving down and giving themselves a quick, twisting motion against the bottom of the trough. If the progress of disease is not promptly checked, it will soon reach a stage where nothing can be done, and the fish grow weaker every day until they begin to die in alarming numbers. One of the best remedies for both diseases is salt sprinkled through the water after the ponds are drawn low, and for a bad case of skin disease a half pint of salt for every gallon of water in the trough is used, or about that proportion. The fish should be watched closely and allowed to remain in the salt water until they become restless and begin to turn on their sides. Then, as fresh water is turned on and the trough fills, a slime will arise and float on top of the water, like a white scum. Coarse sand should be kept in the trough for the fish to rub themselves against. Salt is also good for the diseased gills and will free them from adhering sediment.

Fungus, "blue swelling," and other diseased conditions sometimes occur, but the most serious diseases of the fry are those just described. Parasites sometimes attack the fish, but if the water is pure and the fish in a healthy condition, they are not troublesome. To keep the fish

that are raised in troughs and tanks in a healthy state, it is well to give them a salt bath occasionally, and a small quantity of salt in their food will at times do them good. A little sediment from the reservoir, or such as collects on stones in the streams, is beneficial to fish if mixed with their food. It seems proper that they should have something of this nature, since all or nearly all of their natural food contains more or less sediment of the kind.

A very serious disease among adult rainbow trout shows the following symptoms: The afflicted fish refuse to take food, and very dark spots, from ¼ to 1 inch in diameter, appear on different parts of the body, varying in number from two or three up to twenty or thirty on each fish affected, a light spot about the size of a green pea appearing on the head immediately over the brain. The fish become restless and seek the shallow water in the corners of the pond, hiding among the plants, and begin to die within twenty-four hours from the time the disease is noticeable. They jump and dart around in the water in a frightened manner, settling back on their tails and sinking to the bottom of the pond in their last struggles. This disease made its appearance at Wytheville in December, 1895; it was first observed among a lot of 637 yearling Von Behr or brown trout that had been delivered at the station on November 29. The first sign of the disease was noted about the 5th of December, and by the 12th of the month 455 of the 637 fish were dead.

These fish were in the nursery during the first stages of the disease. The water in which they were held passed from them through an empty pond into a second one containing about 1,000 large rainbow trout that had recently been stripped of their spawn. On the morning of December 23 the disease made its appearance among the latter, and by 4 o'clock in the afternoon of the same day 56 of them had died. Salt was applied and the water in the pond was drawn down to about 300 gallons, and 150 pounds of common salt were sprinkled evenly through it. The fish were allowed to remain in this brine about 15 minutes, when they showed signs of weakening by turning on their sides; then fresh water was turned on freely. Good results were at once noticeable, the fish became quiet and appeared to rest more easily, and steadily improved, another application not being necessary. The final result was that 70 per cent of the adult rainbow trout that had been treated with salt were saved, while of the yearling brown trout that were not thus treated nearly 71½ per cent died.

Foul ponds cause disease, and if the fish become sick from this reason, they must be removed to a clean pond at once and given a salt-and-clay bath, which is applied as follows: While the salt bath, before described, is being given, 2 or 3 bushels of clay are placed in the reservoir or supply-trough, and when the fresh water is turned on after salting, the reservoir is flushed for 30 minutes with roily water from the clay, and after the latter is washed away an increased amount of fresh water is turned on for ten days or more.

Adult fish are very liable to be affected with fungus, which generally appears after a bruise or hurt, or when the fish are in an emaciated condition. If the trouble results from an injury, it can often be cured before it spreads to the sound flesh, but if fungus spreads like a slimy web all over the fish, it is fatal. Fish must be handled very carefully during the spawning season to prevent scarifying the body in any way, as they are especially susceptible to fungus at that period. Should it occur, the fish must be caught at once, rubbed with salt on the affected part, and then released in a pond or tank by itself, where it can be caught for further treatment in a day or two, while those affected all over the body should be killed and thrown out at once.

"Glassy eggs" may be the result of overretention of the eggs on the part of the parent fish. If the eggs are not delivered within a reasonable length of time, say from 36 to 48 hours after they fall from the ovaries into the abdomen, they are surrounded with a thin watery fluid, having a glassy appearance, which if allowed to come in contact with water will change to a milky white, and the eggs absorbing this fluid become hard and "glassy," after which fecundation is impossible. Many thousand eggs have been lost annually on this account, and many brood fish lost or rendered worthless from the same cause. The fish in captivity will not spawn of their own accord unless they have access to gravel or earth in which to make nests. If attention is not given to the spawning fish and their eggs taken when ripe, they soon become very dark in color, the abdomen swells, and sometimes the head will enlarge, causing the eyes to protrude. Under these conditions the fish will die in a few days, but with free and easy access to the raceway they will not often be thus affected.

THE BROOK TROUT.

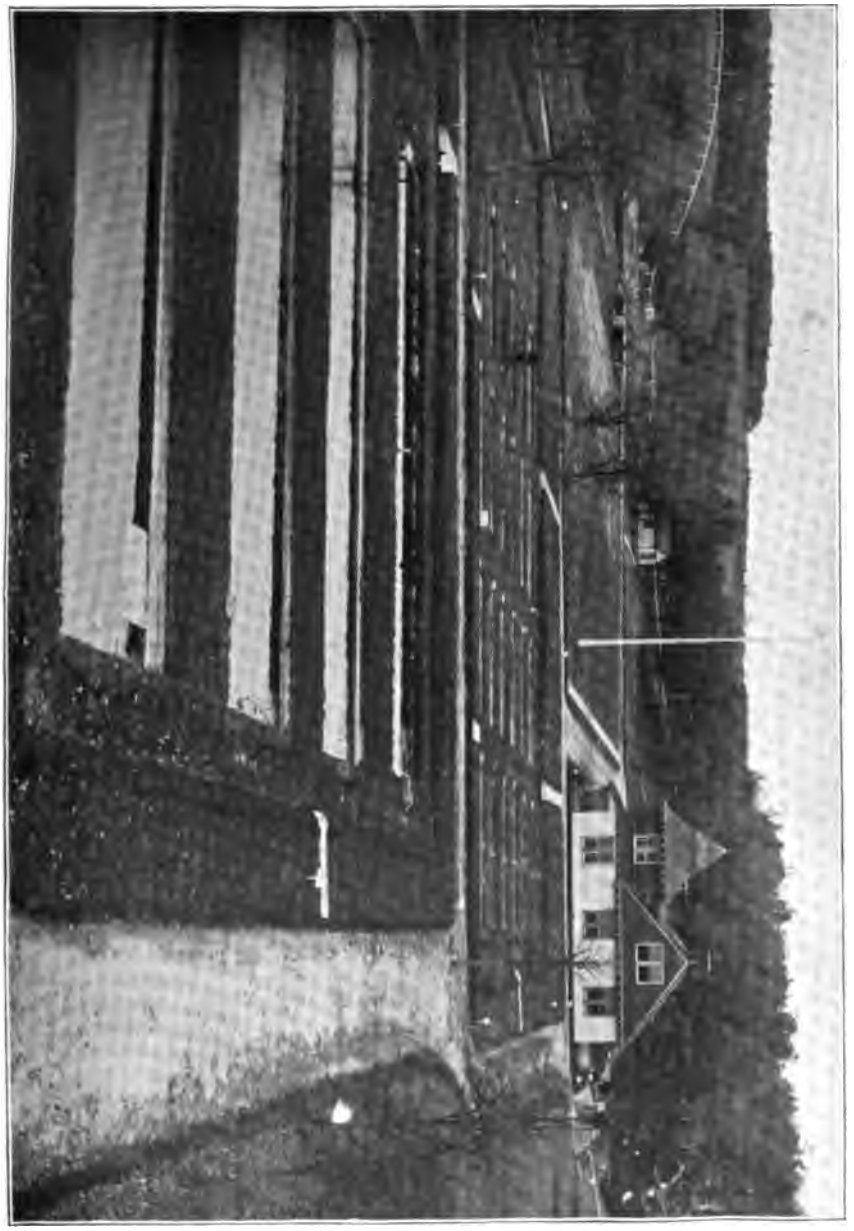
DESCRIPTION OF THE FISH.

The brook trout or speckled trout (*Salvelinus fontinalis*) is one of the most beautiful, active, and widely distributed of the American trouts. It prefers clear, cold, rapid streams, and belongs to that group of trout known as charrs, characterized by the presence of round crimson spots on the sides of the body. Other members of this class are the saibling or charr (*S. alpinus*) of Europe and Greenland; the Sunapee trout (*S. alpinus aureolus*), found in parts of New Hampshire and Maine; the blueback trout (*S. oquassa*) of the Rangeley Lakes in Maine, and Dolly Varden trout, red-spotted trout, or bull trout (*S. malma*) of the Pacific States and Alaska. The lake trout also belongs in this group.

The general form of the brook trout's body varies considerably, sometimes being elongated and sometimes rather short, but the usual depth is about one-fourth or one-fifth of the length. The head is large and blunt, and is contained 4½ times in the body length. The large terminal mouth is provided with teeth on the jaws, tongue, and palate bones, and also with a small patch on the vomer. The eye is placed high in the head; its diameter is about one-sixth the length of head. The gillrakers on the first arch number about 17, of which 11 are on the lower arm. The scales are very small and numerous; about 230 are in the lengthwise series, and 35 above and 35 below the lateral line. The dorsal and anal rays are 10 and 9, respectively. The tail is square or slightly lunate in the adult, forked in the young.

There is considerable variation in the color of this trout, dependent on local conditions, sex, and age. The head, back, and sides of the body, dorsal and caudal fins are of a grayish or greenish color; the back, head, dorsal, and base of caudal are mottled with dark green or black. In the male there is a reddish band along side of belly. Along the middle of the side are numerous round light-red spots surrounded by whitish or light-brownish circular areas. The lower fins are dusky, with a pale or cream-color anterior border bounded by a black streak; remainder of fin often red in breeding males. The brook trout may be distinguished from the other charrs by the dark-brown or black marblings on the back and the general absence of spots on the back.

The parr-marks, which are always present in young trouts and salmons, are often found in large brook trout, and may even be permanent in aquarium or pond specimens and in wild fish with a restricted environment. These marks, which in the brook trout are about 8 in number, are large, dark, vertical blotches or bars extending along the sides. Persisting parr-marks are shown in the accompanying colored illustration of an artificially hatched and reared brook trout. (See frontispiece.)



MATCHERY AND REARING-PONDS FOR TROUT AT MANCHESTER, IOWA.

FOOD, SIZE, ETC.

The brook trout has a voracious appetite and takes advantage of every opportunity to satisfy it except in the spawning season, when it takes no food at all. It is strictly a carnivorous fish, its food consisting chiefly of crustacea, mollusca, and various forms of insects and worms. When pressed with hunger it does not hesitate to devour its own kind.

The size of these fish varies in different localities, usually in proportion to the abundance of natural food and to the size of the body of water in which they are found. They seldom, however, exceed 2 pounds. The Au Sable River trout will rarely run as large as 2½ to 3 pounds, but in other rivers of Michigan larger examples are occasionally found. In southern New York they seldom weigh over 2 pounds, while in the Rangeley Lakes, of Maine, they have been caught weighing 10 pounds. The rate of growth also varies with the surrounding conditions and is more rapid in water of higher temperature and with a plentiful supply of food. Under favorable circumstances an average growth for the first year is from ¾ to 1 ounce, in two years 8 to 10 ounces, in three years about 1 pound.

While not of any considerable commercial importance, the brook trout is highly esteemed as a table delicacy on account of the flavor and quality of its flesh, and, as it is very game, it is much sought after by sportsmen. Those from clear, swiftly flowing streams do not grow so large as those found in quiet and deeper waters, but are superior in quality and appearance.

RANGE, SPAWNING, ETC.

The natural range of the brook trout in the United States is from Maine to Georgia and westward through the Great Lakes region to Minnesota, and in Canada from Labrador to the Saskatchewan. Owing to its hardy nature and ability to adapt itself to new surroundings, it may be successfully transplanted into suitable streams, and has been extensively introduced into waters to which it was not native, in Michigan, Wisconsin, and Minnesota, many of the waters of the Rocky Mountains and the Pacific Coast, the Eastern States, and the creeks and rivers of the Alleghany range of mountains. With the possible exceptions of the rainbow trout and steelhead it is the hardiest member of the salmon family and will make a brave struggle for existence even with adverse surroundings. All streams can not be successfully stocked with this species; the temperature of the water must not be too high nor the flow too sluggish, although an unfavorable temperature is no serious obstacle if the speed of the current is great enough to insure a sufficient aeration of the water, or if there are creeks fed by springs flowing into the main stream to which the fish can run. The best streams are those with a gravelly bottom, clear shallow water, and a steady current, and waters to be stocked must contain a sufficient amount of natural food and suitable places for spawning.

The Michigan streams exemplify the practical results attained in the introduction of brook trout in new waters. The Au Sable River was long thought to be especially adapted for this species, but it abounded with grayling, and until this beautiful fish began to disappear no movement was made toward introducing the brook trout. The lumber interests of that section made it necessary to use the river for conveying logs to various points downstream, and, as the log-driving could be done only during the spring freshets, it came just at the time when the grayling were on their spawning-beds. They were driven away and the beds destroyed by the plowing of logs through the river bottom each year, till the fish gradually began to disappear. The brook trout was suggested as the proper substitute, because its spawning season is in the autumn when the river is undisturbed, and the Michigan Fish Commission began the work by planting 20,000 fry in the year 1885. Though additional plants were made from time to time, both by the Michigan and United States Commissions, no results were observed for some years, and it was thought that the work had been a failure. But the natural instinct of the fish had caused them to push from the main river into the small tributaries, where they multiplied and grew during these years till they finally crowded down into the river itself. Here they found as suitable a home as in the small streams, and their numbers gradually increased till now the stream is completely stocked.

In the autumn of 1895 a camp was established for the United States Fish Commission 9 miles below the village of Grayling for the purpose of taking spawn from wild fish. The work was confined to rod-and-line fishing until the spawning season opened, when it was found necessary to adopt some other plan, as at this time the trout refuse to feed. During the five weeks, in which the rod was used exclusively, 3,000 spawning fish were taken. A small seine was then used for capturing the fish, by hauling it at right angles to the current of the river, directly across the spawning-beds, which thickly dotted the river bottom in some places. By this method a tubful of trout at one haul was often taken, and during the period the fish were running between 8,000 and 10,000 were obtained. This illustrates the abundance in which this species is found in a river to which it has been transplanted. A conservative estimate would place the number of trout taken from this stream in the season of 1895 at 100,000, perhaps 25 per cent being rainbow trout. Other waters of the State have been successfully stocked, so that the northern half of lower Michigan now contains a network of trout streams, made by introducing this fish into waters where it was not indigenous.

In its native haunts, whether in lake or stream, the brook trout is usually found in the same clear, cold, spring water, and prefers brooks or streams flowing swiftly over gravelly bottoms. It pushes from the rivers into the small streams, seeking the headwaters, searching out

deep pools and eddies where it can lie concealed beneath the shelter of grassy banks or logs, and see without being seen. Under artificial conditions it endures greater temperature than in its native waters, where it is seldom found in water over 60° to 65°. It thrives at much higher temperature in swift, well-aerated streams than in sluggish waters.

The brook trout spawns in autumn during the falling of the water temperature. The season, which usually lasts about two months, begins earlier in northern latitudes, in the Lake Superior region in September or even August, while in New York, New England, and lower Michigan it commences about the middle of October.

As the spawning time approaches the fish push up toward the shallower waters where the female selects a spot near the bank of the stream and prepares her nest by washing out the sand with her tail and pushing aside the gravel with her nose. After forming a slightly concave depression she deposits a part of her eggs on the newly cleansed gravel, and the male—which up to this time has been playfully swimming around the nest—emits milt upon them almost simultaneously. The female then covers the eggs with loose gravel. The spawning, impregnating, and covering are repeated continuously until the eggs are all laid. After the spawning-ground is once selected it is hard to drive the fish away, the female especially returning to the same spot at the earliest opportunity. A female has been taken from her nest and marked and then returned to the water a mile down the stream, and the next morning was again found on the same bed.

The eggs vary in size, but are usually one-sixth of an inch in diameter. The number yielded by one fish depends on its size and age, yearlings usually producing from 150 to 250, two-year-olds 350 to 500, and older fish 500 to 2,500. The time necessary for developing the eggs is dependent on the temperature of the water, varying from about 125 days in water at 37° F. to about 50 days in water at 50° F.

TROUT-CULTURE IN AMERICA.

The first attempt at artificial trout-culture in America was made in Ohio in 1853 with marked success. Further satisfactory trials were made in 1855 and 1859 in Connecticut and New York, and in 1864 a hatchery was established in New York which carried on the work on a large scale. Somewhat later the work was taken up by the State and United States governments and is now very extensively conducted in all parts of the country. The methods described in the following pages are those which have been found advantageous at the Northville Station and are there pursued.

SPAWN-TAKING.

Eggs are obtained from brood-fish held in ponds and from wild fish obtained at a field station located on a tributary of the Au Sable River near its junction with the river. As the spawning season approaches, the brood-fish at the station are sorted according to age and size and transferred to spawning-ponds, which are seined once a

week for ripe fish in the early part of the season and later on three or four times a week. Great care is used in manipulating the seine, and when its ends are drawn up on the bank the fish are transferred with dip-nets from the bag of the seine into tubs, care being taken not to overcrowd the tubs. The fish are then examined; those which are not ready are returned to the pond, while the ripe males and females are placed in separate tubs or buckets. A good spawn-taker can tell at a glance if a female is ripe, and only in such condition should an attempt be made to take her eggs. As soon as these fish have been stripped and the eggs fertilized, the spent fish are liberated in a separate pond to avoid rehandling them during the season.

After the males and females are separated, an ordinary milk-pan coated with asphaltum paint on the inside, to prevent rust, is dipped in water and allowed to drain, leaving only the water that clings to the inside. Taking a female from the tub, the spawn-taker holds her as quietly as possible till all struggles cease, and then pressing gently with the thumb and forefinger a little above the ventral fins, passes his hand down the belly to the oviduct, repeating the operation till all the eggs are extruded. The eggs are immediately impregnated with milt, obtained from the male in a similar manner, except that more force is necessary and the pressure is made at a point about midway between the ventral and anal fins.

The contents of the pan are next lightly stirred with a feather to insure impregnation of all the eggs possible. They now present a milky appearance and are washed in as many changes of water as is necessary to thoroughly cleanse them from milt and refuse, when the pan, half-filled with fresh water, is placed in running water to keep the eggs at a low temperature. In 30 to 60 minutes, according to the temperature of the water, the separation of the eggs ensues.

THE HATCHING APPARATUS.

The apparatus at Northville is arranged as follows: A tank 15 feet long, with a partition running its entire length, is so placed that its lower end rests upon the upper end of a similar one 13 feet long, which differs from the upper one only in that it contains two boxes less. Nine partitions, placed crosswise of the tank, form, with the lengthwise partitions, a double row of eight compartments, each of which is 19½ inches long and 15½ inches wide, and is provided with a waste-water channel or sluiceway leading into the next compartment. In these compartments are placed Clark hatching-boxes.

The Clark box is 18 inches long, 14 inches wide, and 9½ inches deep, and is made from ¾-inch dressed whitewood lumber. On its under side the box is provided with feet, 1½ inches square and ⅜ inch thick, to allow a free circulation of water under it and to prevent it from resting upon any sediment or refuse that may be deposited on the bottom of the tank; and on the inside in each bottom corner is fastened a block, ⅜ inch thick by 1½ inches square, to support the trays. Five circular openings, ⅞ inch in diameter, permit the escape of water from the box. A slot is

SELECTING AND STRIPPING RIPE TROUT, NORTHVILLE, MICH.

cut in one end of the box so that water from the compartment above can not flow into the one below without falling into and passing through this box. Upon the feet or risers inside the box rest 9 trays, placed one upon the other, the end of the box which contains the slot fitting snugly against the upper end of the compartment, in which is fitted a tin overflow. The whole is held in place by a crossbar or binder, which fits in ⅜-inch grooves cut in both sides of the tank. The binder, resting on the box, keeps it from rising in the water, and is provided with feet so placed as to prevent the trays from floating in the box itself. The trays are perforated zinc or fine wire netting, tacked on a frame 16 inches long and 7 inches wide inside measurement, made from ¾-inch pine 1¼ inches wide.

CARE OF THE EGGS.

The eggs after separating are placed in troughs, the bottoms of which are covered with half an inch of gravel, and here they remain till the eye-spots begin to appear.* During this interval of about 30 days the principal care consists in sorting out bad eggs, and, with a feather, gently changing the position of good ones to prevent sediment from collecting on them. At the expiration of this period they are ready for transfer to the hatching-boxes. They are drawn off the gravel by means of a siphon into a tub or bucket which has been half filled with water to preserve them from injury and then carefully dipped into a glass graduate, measured, and placed on the hatching-trays. The trays are arranged in the boxes in stacks of nine, and 5,000 eggs are allowed to each tray except the top one, which is left empty and serves only as a cover. The eggs from domesticated brook trout measure 350 to 450 per fluid ounce, depending on the age of the fish. Eggs from wild trout collected in the Au Sable River measure 450 to the fluid ounce.

At intervals of from 3 to 6 days during the period of incubation, in order to remove the bad eggs, the trays are taken from the boxes and placed in a shallow picking-trough through which a stream of not more than 3 gallons per minute is flowing. This trough is only wide enough to allow perfect freedom in handling the trays when putting them into or removing them from it, and only of sufficient depth to allow the eggs to be fairly covered. Nailed to the bottom on each side is a ½-inch strip, 1½ inches wide, and running the entire length of the trough. These strips permit the free passage of water beneath the trays, as otherwise the water would flow over the tops and a great many eggs would be lost. The bad eggs are removed with tweezers, the labor being usually performed by girls, who become so expert that one girl will often remove 100 bad eggs per minute.

After the incubation has reached a stage where the fish are beginning to break their shells, the hatching-box is taken out and reversed,

*The practice of holding the new eggs on gravel until the eye-spots begin to appear is pursued at Northville with eminent success, but at the other trout hatcheries of the Commission, where equally good results are obtained, it is customary to transfer the eggs to the hatching-trays as soon as they are impregnated, as is described in the chapter on the rainbow trout.

the open end being fixed snugly against the lower wall of the compartment. The closed end of the box being thus placed upstream, the water is prevented from entering except through its former exit, the holes in the bottom of the box, and is thus forced up through the box, with an exit at the top which prevents the sacs of the hatching fish from being forced, by pressure from above, down through the screen, as would be the case if the box were left in its former position.

When the process of hatching is nearly completed the trays are removed and emptied into a large pan filled with water, where the dead shells and other refuse, being of low specific gravity, rise to the top and can be easily poured off. This is called washing the fish. The fish are then replaced upon the trays and returned to the hatching-boxes, where they remain until the food-sac is nearly absorbed, a period of from 25 to 40 days, according as the temperature varies from 50° to 38° F.

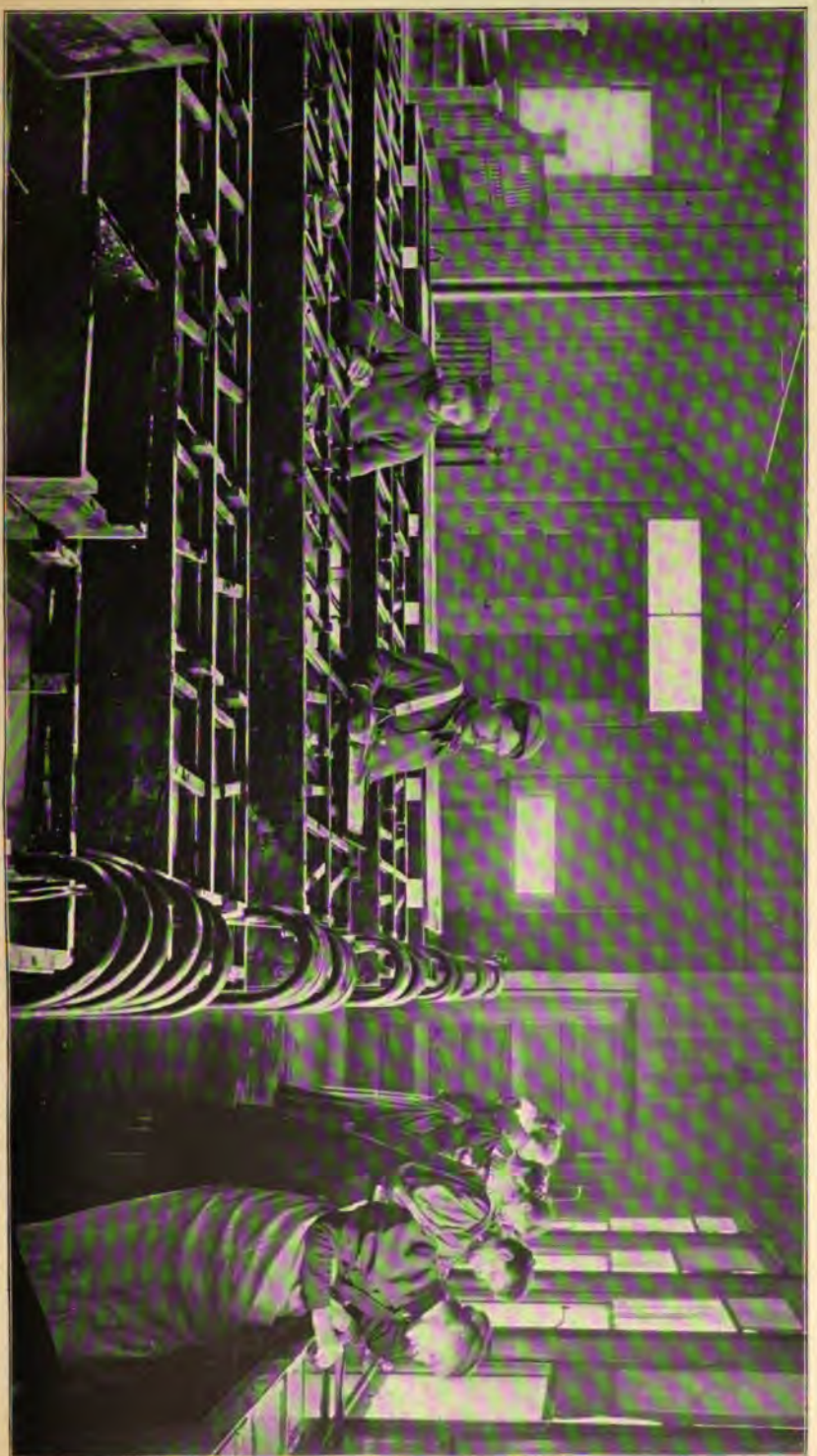
The young fry, deprived of their food supply by the absorption of this sac, must soon be placed where they can get their sustenance elsewhere. They may be planted in waters suitable to their nature, or reared for breeding or other purposes at the station.

THE FIELD STATION.

The egg-collecting station previously referred to is on a tributary of the Au Sable, flowing about 1,000 gallons per minute. A dam is thrown across the stream and 100 feet above is a screen to prevent the fish from escaping in that direction. The dam is simply constructed by banking up mud, sand, and turf, and has a frame sluiceway 3 feet long, 2 feet wide, and 2 feet deep. In the sluiceway is inserted a double screen of ¼-inch mesh wire netting, two screens being necessary to keep the overflow clear and reduce as low as possible any loss of fish through this outlet. The inclosure accommodates about 10,000 fish. Fish are obtained with rod and line, until they begin to run from the deep pools upon the spawning-grounds, when much better results are obtained with nets. With an ordinary seine at the approach of the spawning season, the fish can be taken in large numbers from their spawning-beds. As the season advances and too many fish are caught that have already spawned, operations are suspended.

As soon as ripe fish are found among those caught on the spawning-beds, the inclosure is hauled with a seine and the fish are looked over twice a week until the eggs are taken. When the season is fairly open the spawn may be taken from most of the fish immediately after they are caught, thus obviating the difficulty of transferring them from the point of capture to the inclosure, in some cases a distance of 3 or 4 miles.

For holding the eggs, two pairs of troughs are placed on standards driven into the bed of the stream, with a passage between them wide enough to admit a man. The water is received through two 1-inch orifices in a bulkhead about 9 feet long, situated at the head of these troughs and fed by a roughly constructed raceway leading from a small spring about 6 rods distant on the hillside. The water from each of the



INTERIOR VIEW OF NORTHVILLE HATCHERY: CLARK BOXES IN FOREGROUND; CLARK-WILLIAMSON BOXES IN BACKGROUND; GIRLS PICKING EGGS AT THE RIGHT.

openings feeds two troughs, so placed that the lower end of the upper one rests upon the head of the other, thus creating a fall of nearly the height of the troughs. Each trough is 14 feet long, 5 inches deep, and consists of a double row of boxes, each box 17 inches long, 15 inches broad, and 2 inches deep, giving a capacity of from 8,000 to 10,000 eggs.

SHIPPING GREEN EGGS.

Green eggs can be safely moved at any time up to and including the eighth day. They are shipped from the field station to the hatchery in cubical boxes constructed from ½-inch pine lumber, just large enough to admit, with a surrounding air space of ½-inch, 19 canton-flannel trays, 18 inches square on the inside, the frames of which are made from ⅞-inch square white pine. The eggs are siphoned from the gravel boxes, as described above, and, using a graduated dipper for the purpose of ascertaining approximately the number of eggs necessary to make them about two deep on the tray, the packer pours them upon the flannel and spreads them as evenly as possible with a feather. The tray is then placed in the box and the operation repeated until eighteen trays are filled with eggs. The nineteenth, or top tray, is usually left empty, but if the weather is very warm it is filled with fine ice. The cover is then fastened down, the box marked, and the eggs are ready for shipment to the hatchery.

PLANTING THE FRY.

In their natural state, as soon as the weight of the food-sac has diminished by absorption enough to permit their rising, the fish begin to take food, and by the time the sac is entirely gone they are probably taking it regularly. When very young fry are transferred to outside waters where there is natural food only, it should be done 8 or 10 days before the sac is entirely absorbed, for, if delayed till after the sac disappears, many will die before they become accustomed to finding food in their new home.

Brook-trout fry are usually transported in ordinary round-shouldered cans of 10 gallons capacity, the number of fish per can depending entirely upon the distance they are to be carried and the facilities for taking care of them en route, such as opportunities for changing the water, supplying fresh ice, etc. For a short trip of from 5 to 10 hours duration, between 4,000 and 5,000 are carried in each can, but where they are to be on the road from 1 to 5 days, it is hardly safe to attempt carrying more than 2,500. The Commission distributes fry by means of its cars, built especially for the purpose, in which either running water is kept upon them or fresh air introduced into the water to make it life-sustaining. Small shipments are made by a special messenger in a baggage car, the railway companies usually offering every available opportunity for changing water, etc. The fish, upon arrival at the railway point nearest their destination, are carried thence by wagon to the stream where they are to be planted, by distributing them in small lots in different places where there is shallow water and a good bottom.

REARING AND FEEDING.

If the fry are to be reared for breeding, one week before the food-sac is absorbed they are changed from the trays to a large pan and removed to the rearing-troughs. Gravel should not be used in these troughs, as the unconsumed food works down into it and, becoming fungussed there, causes a greater spread of disease and increases the labor of caring for the fish.

The time to begin feeding the fry is readily ascertained by trial. If they rise to minute particles of food thrown upon the water, they are then ready for regular feeding. The time and frequency of feeding young fish, the kind of food, and the manner of feeding them, are of the greatest importance. Liver gives better results than any artificial food, and its preparation is very simple. Beef livers are ground by a meat-chopper and then strained through a fine-meshed screen, a thick pudding being made by the addition of water. A small portion, only such an amount as the fish will readily eat at a time, is spread upon the surface of the water with a feather, and they are fed as often as six or eight times per day until they become used to the new diet. As they grow older the quantity of food may be increased but the fish are fed less frequently. At this stage the young fish have such a precarious hold upon life that too much attention can not be given to their care. Not more than 20,000 can be held with success in a feeding or rearing trough, and a regular stated supply of water is kept flowing through to prevent disease, and the fish are properly thinned out in order to prevent loss by suffocation when they increase in size. About 30 gallons of water per minute are sufficient for 20,000 fry, though this quantity is increased as the fish grow stronger and are able to breast a heavier current.

In the spring season, when the water begins to grow warm, the fish require more room than the feeding-troughs afford, and it is then necessary to transfer them to ponds. The Northville rearing-ponds are 5 feet by 20 feet, made from 2-inch pine boards and provided with a gravel bottom. A pond of this size accommodates from 10,000 to 20,000 fry till the middle of the summer, when the number is reduced to as low as 5,000. It is advisable to place not more than 5,000 in the pond at first to avoid the labor of reducing the number of fish at different times, and also because crowding into too small a space retards their growth.

At first the fish require coaxing to induce them to eat, as the change to their new abode has frightened them, and a great deal of patience is necessary in their treatment. They are fed at regular intervals three times per day. As their appetites are poor for the first few days, the liver will fall to the bottom and foul the pond, if great care is not exercised, and three fourths of an hour is not too long for feeding 5,000 fry. The time occupied in feeding is diminished and the amount of food increased according to the judgment of the fish-culturist; but their appetites should never be completely satisfied.

REMOVING GREEN EGGS FROM SHIPPING-TRAYS, NORTHVILLE.

PACKING EYED EGGS, NORTHVILLE.

By early winter they will have grown to a length of from 3 to 6 inches, necessitating a change to a larger pond. The Northville breeding-ponds are 20 by 75 feet, and are constructed in the same manner as the rearing-ponds. One of these larger ponds accommodates 10,000 yearlings, 5,000 two-year-olds, and about 3,000 fish from three to five years old. By the time the fish are three years old and over, less care is required in the preparation of their food, as the liver may be given to them in pieces half an inch in diameter.

PACKING EYED EGGS FOR SHIPMENT.

Eyed eggs prepared for shipment in the following manner have been sent from Northville to all parts of the United States with practically no loss: The trays upon which the eggs are to be shipped are made from the same materials as those upon which green eggs are carried, but are usually much smaller. Fewer eggs are placed upon a given surface than is the case with green eggs. For example, 10 trays, 12 inches by 12 inches, will carry 50,000 eggs; 8 trays, 10 inches by 10 inches, 32,000 eggs; and 5 trays, 8 inches by 8 inches, 12,500 eggs; or 5,000, 4,000, and 2,500 eggs per tray, respectively.

The trays are allowed to stand in cold water till thoroughly soaked, and are then drained off and taken to the packing-room. After the dead eggs have been removed from a box, the trays are taken out, drained, and removed to the packing-room. A ¾-inch wooden frame, made to fit the inside of the canton-flannel tray, is then inserted, the eggs are carefully brushed with a feather from the wire trays and spread as evenly as possible upon the flannel. The eggs have been previously measured at the time when they were removed from the gravel to the hatching-box, so the number to be placed upon each tray can be easily determined. After the eggs are spread upon the flannel, the inside wooden frame is taken out, leaving a ¾ inch margin around the inside of the tray. A square of mosquito netting large enough to lap over on all sides of the tray is laid upon the eggs and tucked down firmly along the inside. Sphagnum moss is scattered to a depth of about ¾ inch upon this netting. The moss is prepared by removing sticks and other foreign matter; it is soaked in water a short time and then run through a clothes-wringer. In spreading it upon the netting the moss is picked apart and made as light and fluffy as possible, to give the eggs plenty of oxygen.

When the required number of flannel trays are packed they are placed one upon another and cleated together on all sides, with boards at the bottom and top. This crate is usually placed, if possible, where the temperature of the air is below freezing, so that the moss may be slightly frosted before the crate is put in the shipping-case.

A case is made large enough to allow a 4-inch space above, below, and around all sides of the crate when it is placed in position. Its bottom is filled with fine shavings, 4 inches deep, and the crate placed upon them as nearly as possible in the center of the case. Shavings

are packed tightly around the crate, a few being thrown in and pounded down securely before more are added. This must be well done, as the shavings are the only means of preventing a change in the position of the crate. The top of the crate is then covered with closely packed shavings and the cover of the case screwed on. By means of rope or iron handles the case may now be moved about with ease, and is ready for shipment.

REFRIGERATOR BOX FOR SHIPMENTS ABROAD.

A double box is used for this purpose. The inside one is 2½ inches larger on all sides than the crate of trays, and the outside one large enough to make a 5-inch space on all sides when the smaller box is placed within it. The trays of eggs are prepared as in ordinary shipments, and when crated are placed in the smaller box upon a frame which is constructed from a ⅛-inch strip, 2½ inches wide, tacked at right angles to the inside and bottom of this box. In the chamber thus formed between the crate and the box is packed finely chopped ice, an exit for the water resulting from its melting being provided by a half dozen openings in the bottom of the box. This box is now packed according to the same plan as that followed with the shipments for a short distance. Where there is an opportunity, it is well to have the case unpacked en route and new ice added.

Eggs have been sent in this manner to England, Mexico, New Zealand, Japan, and South America.

U. S. COMMISSION OF FISH AND FISHERIES,

GEORGE M. BOWERS, Commissioner.

ARTIFICIAL PROPAGATION

OF THE

LAKE TROUT, GRAYLING, AND WHITEFISH.

Extracted from the Revised Edition of the Fish Manual.
Pages 91 to 120, Plates 30 to 39.

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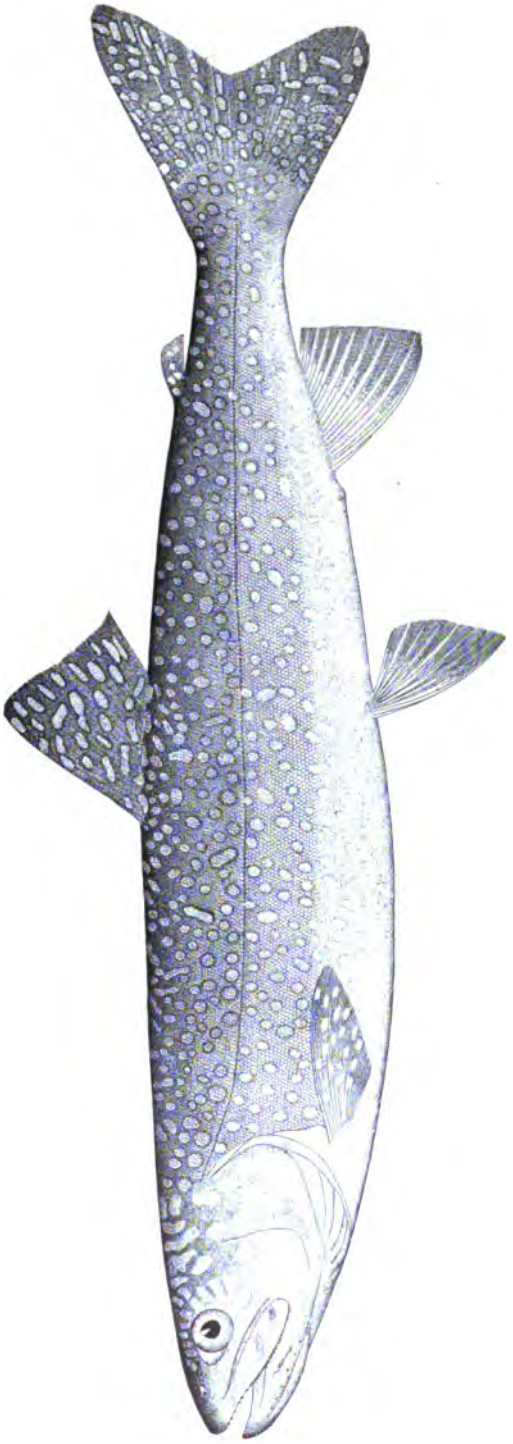
1903.

PLATE 30.



CRISTIVOMER NAMAYCUSH. *Lake Trout.*

THE LAKE OR MACKINAW TROUT.

DESCRIPTION OF THE FISH.

This handsome species (*Cristivomer namaycush*), the largest of the trouts, is classed with the charrs. It has an elongated body, the length being about 4½ times the depth. The head is large, flat above, and about as long as the body is deep. The mouth is large; the maxillary bone extends beyond the eye and is half the length of the head; the jaws have strong teeth. A peculiarity of the vomerine bone distinguishes this fish from the genus *Salvelinus;* it has a crest provided with teeth extending backward from the shaft of the bone. On the hyoid bone the teeth are in a cardiform band. The eye, placed near the top of the head, is contained about 4½ times in length of head. The caudal fin is well forked. Both the dorsal and anal fins contain 9 to 11 rays. In the straight lateral line there are about 200 scales. Branchiostegals 11 or 12.

The coloration is quite variable in fish from different localities. The general color is usually dark gray. The body, head, and fins are covered with small discrete rounded spots, usually of a pale color, but often tinged with reddish. On the back and top of head there are fine vermiculations, as in the brook trout. Examples from some lakes of Maine and eastern Canada are nearly black, and Alaskan examples are often very dark; others are quite pale.

That variety of the lake trout known as the siscowet (*Cristivomer namaycush siscowet*), found only in deep water in Lake Superior, is shorter and paler than the typical fish and has weaker teeth and a shorter head; it is, however, chiefly characterized by an excessive fatness, which greatly reduces its food value.

The present chapter is devoted to trout of the Great Lakes and the methods of propagation employed at the station of the United States Fish Commission at Northville, Michigan.

RANGE, FOOD, ETC.

The lake trout is found throughout the chain of the Great Lakes, and the inland lakes of northern New York, New Hampshire, and Maine; the headwaters of Columbia and Fraser Rivers, streams of Vancouver Island, and even waters within the Arctic Circle are said to contain this species. With the exception of the whitefishes, it is perhaps the most numerous food-fish of the Great Lakes, and formerly none exceeded it in weight except the sturgeon. Instances are cited by fishermen and others of lake trout weighing as high as 125 pounds, and its average weight has been given at from 20 to 30 pounds, but of late they are rarely found exceeding 18 or 20 pounds. Possibly, if unmolested by

man, they might again reach the enormous weight of early citations, their sluggish movements and voracity being conducive to such a result.

The nature of their environments has a decided influence on the characteristics of this species; the temperature of the water, food, and character of bottom entirely changing the marking and peculiarities of these fish in their various habitats.

Until recently it was commonly thought that the principal food of the lake trout was the young whitefish, and for this reason the fishermen of the lakes were generally unfavorable to its artificial propagation. The error of that belief, however, is now generally conceded, though no doubt quite a number of young whitefish become food for trout during each season. But as the habits of the lake trout take it to deep water immediately after spawning, while the young whitefish remain in shallows, the few which are destroyed in this manner are either stragglers from shoal to deep water or taken by trout aimlessly wandering from their natural range. The lake trout is an omnivorous feeder and has a ravenous appetite. It greedily devours all fishes possessing fins of flexible character, and jackknives, corncobs, and other articles equally indigestible have been found in its stomach.

The spawn and fry of lake trout suffer from the same enemies as the young of all fishes, but the mature fish are too formidable for other species to prey upon. They are troubled with a few parasites. Occasionally individuals, very thin in flesh and sickly-looking, known as "racers" by fishermen, are found swimming near the surface; no sufficient cause has been discovered for this condition, as they are no more afflicted with parasites than healthy fish.

IMPORTANCE AND ABUNDANCE.

The trout fisheries of the Great Lakes are second in importance commercially, the whitefish ranking first. At one time trout were so plentiful that they did not command a price at all proportionate to their edible qualities, but as the fishing continued the catches decreased, until about the year 1886 the market price of trout became equal to that of its more delicate rival. At this time it became evident to the Federal and State governments, as well as to those dependent upon this industry for a livelihood, that decisive steps ought to be taken toward providing against the extermination of this valuable food-fish. Artificial hatching was commenced that year with the object of restocking the Great Lakes. The work progressed only in a limited way up to 1892, when the output of both the United States and Michigan Fish Commissions reached something like its present proportions. During the season of 1895 the United States Fish Commission station at Northville secured over 11,000,000 lake-trout eggs. As indicative of the success attending the plants of lake trout, it may be remarked that for a short period during the season of 1896 the fishing-boats, which had been working to their fullest capacity, ceased operations, the market being glutted and the remuneration not being commensurate with the labor, hardship, and capital invested.

The method of capture is by gill nets, pound nets, hook and line, and in winter by spearing through the ice. The majority, however, are taken from gill nets operated by steam tugs. These boats are fitted out with the most approved appliances of their trade and have quarters on board for the men employed, usually a crew of 8 or 10. Some of the tugs carry 5 or 6 miles of nets and catch in one lift from 1,000 pounds to 4 or 5 tons of trout. Fishing is done from the time the ice breaks up in the spring until late in the fall or early winter, the work ceasing only when the weather and ice no longer permit operations. In some localities the water becomes so warm during summer as to be detrimental to the nets, and consequently at such points there is a lull in the work for a few weeks. Lake trout spawn on the reefs and live in deep water during the remaining time, and their migratory habits govern the movements of the tugs, the fishermen necessarily moving from one point to another. The small gill-net boats, carrying sails and handling a few hundred feet of nets, confine their operations to more shallow water and fish only during the spawning season. At Detour, Lake Huron; at some points in Lake Superior, and on the north shore of Lake Michigan pound nets are in use, but usually these nets are not used for the capture of lake trout.

NATURAL SPAWNING.

Spawning commences the last of September in Lake Superior and later in the lower lakes, since the water does not become sufficiently cool here as early as in the headwaters. In Lakes Huron and Michigan the height of the season is in the early part of November, and spawning continues to the first of December. The spawning-grounds are on the reefs of "honeycombed" rocks, 10 to 15 miles from shore, and during the reproductive period vast numbers of fish visit these places, spawning in a depth of from 1 to 20 fathoms. Owing to the great depth of water, the shyness of the fish, and the severity of the weather at this time, nothing definite has been determined as to the fish's maneuvers while spawning. The supposition is that the female lies over an indentation of the rocks and allows her eggs to settle into the "honeycomb" cavities; fragments of the rock with the cavities filled with eggs having been hauled in by fishermen when lifting their nets. No doubt the general characteristics of the *Salmonidæ* are carried out by the lake trout as far as the conditions in which they exist permit.

An instance has been known of a Mackinaw trout of 24 pounds weight containing 14,943 eggs; but not over 5,000 or 6,000 eggs are commonly found, and 1,000 eggs to the pound of fish may be accepted as a general rule, after the trout have attained maturity, at three years of age.

A much smaller variety, called the shoal trout, is found in Lake Huron in the vicinity of Alpena, and in Lake Michigan near Charlevoix and Northport, but its weight compared with its length is greater than that of the true Mackinaw trout, and the markings and appearance of the two also differ. The shoal trout spawns in September, about a

month earlier than the lake trout, on a cobble, bowlder, or gravel bottom, and in from 2 to 8 feet of water.

OBTAINING THE EGGS.

During the spawning season men are employed by the different lake-trout hatcheries to accompany the tugs to their fishing-grounds and strip the ripe fish as they are taken from the nets. These "spawn-takers," or "strippers," must possess strong constitutions to withstand the many hardships to which they are subjected. Where very extensive nets are operated by a boat and fishing is exceptionally good, two men are detailed to the same ground, one as spawn-taker, the other as helper. Pans, pails, and dippers are taken on board and made ready by the time the nets are reached. As the net is lifted the men disentangle the trout and throw them on deck, where the spawn-takers sort them over, taking the eggs from ripe females and impregnating them with milt from the males. During very severe weather the fish are thrown into the hold instead of on deck and the work is done there.

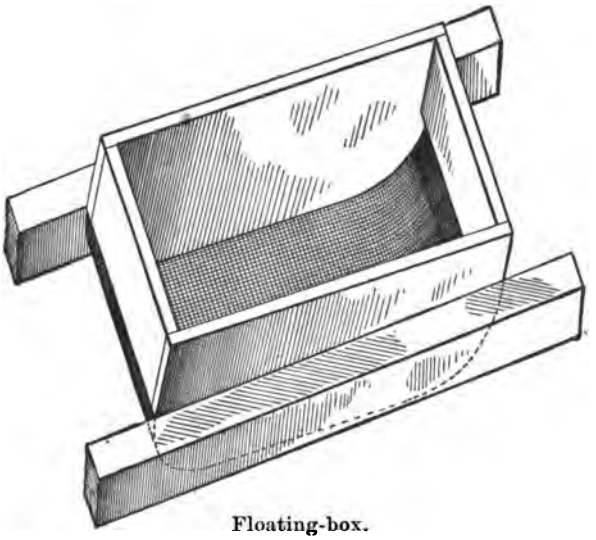
The manner of taking the eggs is similar to that used in taking spawn from other trouts and salmon. First, the female is taken and the eggs, if mature, are gently stripped into an ordinary milk-pan and then impregnated with milt from the male. This operation is repeated until the pan is about half filled, when the eggs are "washed up" and poured into a 5-gallon pail. The "washing-up" process is performed by filling the pans with water and then allowing it to run off, repeating the same until the water which is poured off no longer appears milky; as the specific gravity of the eggs prevents their rising to the surface this can be done without loss if ordinary care is exercised. The pans are refilled and emptied in the same manner until the pail is half or three-fourths full, when it will contain about 75,000 eggs; other pails or buckets are brought into use as often as necessary. To keep the eggs from dying, the water is changed in the large pails every hour until the eggs are taken from the boat and transferred to flannel trays or floating-boxes. All pans, pails, and other metallic apparatus are coated with asphaltum paint to prevent rusting, as rust is fatal to the eggs.

When the weather is so cold that there is any chance of eggs freezing to the pan, two pans are sometimes used. The outside one is partly filled with water, upon which floats the pan that is to receive the eggs as they are stripped. The pan of water protects that part of the inside pan where the eggs rest and in that way their temperature is kept above the freezing-point.

SHIPPING EGGS TO THE HATCHERY.

When spawn-takers are operating at a distance the eggs are held at field stations located at convenient points, whence they are sent to the hatching-house as soon as possible, but if the stations are at isolated points on the lakes it is often necessary to hold the eggs for several days, and occasionally weeks, before means of transportation can be obtained. In such a case the eggs are held in floating-boxes, which are made 2½ feet by 1½ feet by 1 foot, with the ends rounded up about 6

inches; the sides and ends are 1-inch pine and the bottoms ¼ inch-mesh iron wire cloth, which is continued over the rounded ends. Cleats are nailed on the sides, one end somewhat lower than the other, to give the box a tilt when placed in water. Each box carries safely about 180,000 eggs, and when it is filled is anchored either in running water or in a sheltered cove of the lake. In the former case a current of water is kept passing through the box, while in the latter the eggs are given a slight motion by the action of the waves upon the surface of the water.



Floating-box.

When eggs held in floating-boxes are to be shipped they are dipped into pails and taken to a place arranged for packing them, located at no great distance away, where a table upon which to place the trays may be improvised from any material at hand.

The trays for packing the eggs are constructed by making a frame of ¾-inch square pine, 18 inches square, inside measurement, with white canton flannel tacked on one side. A case to contain the trays is made of ⅞-inch pine, large enough to hold 19 of these trays one over the other, allowing for a surrounding air-space of half an inch. Half-inch cleats are nailed on the bottom and at the corners of the box on the inside, so that the trays are securely held in position. A hinged door is at the top, handles are at the sides, and the whole is painted and of neat appearance.

For transferring the eggs from pail to tray a graduated dipper is used, which has a capacity of about 10,000 eggs, the number usually placed upon each tray. Thus, in a case containing 18 trays 180,000 eggs may be stored. A dipperful is placed upon each tray. The canton flannel holds water for some time, and if a little is poured upon the eggs, which are at first bunched in the center, they settle and spread, and by a slight dexterous movement, acquired by practice, are evenly divided over the tray. Ten thousand eggs on a surface 18 inches by 18 inches are about two deep, and if kept at the proper temperature and handled carefully they may be carried a long distance. After the eggs

are spread upon the tray it must be drained before being placed in the case, for eggs slightly moistened will live for a longer time in open air of the right temperature than in dead water. The tray is easily drained by slightly tipping it, so that the water will run out at the edges where the flannel is tacked on the frame. The trays are then placed in the case, eighteen filled, the top one empty.

If the case is to pass through a varied air temperature, moss is packed in the space between the trays of eggs and the sides of the shipping-case for protection against abrupt changes in the weather.

When necessary to hold eggs on the trays for any length of time, as is often the case, each tray must be taken out and sprinkled with water at least every 24 hours. When they are held for a longer period than 4 or 5 days they must be taken from the trays and placed in a tub of water and there washed in the same manner as described in taking spawn. When adding water, care is taken that it does not strike the eggs with such force as to injure them, the dipper either being held down in the eggs or the water poured against the side of the tub a little above the surface of the spawn, which gives them a steady whirling motion and at the same time does them no injury.

The manner of transferring eggs from trays to a tub is very simple. After filling the tub with water to about a third of its capacity, the tray is placed in water at an angle of about 45° with its surface. Most of the eggs will slide down this incline into the tub, and what few remain may be washed down by pouring a little water on the uppermost side of the tray. After the eggs have been given a good washing they are replaced on the trays and returned to the cases, as described above.

The eggs are shipped in charge of a messenger, if possible, to see that the cases are not roughly handled or tilted and the contents jarred or bunched while being placed in the baggage car. While on the road they must be kept in the coolest place on the car, providing that the temperature is not below 28° or 30°.

It can be readily seen that the percentage of lake-trout eggs hatched can not be so large as with other species of trout. The rolling and pitching of the tugs and other boats upon which the spawn-taker is operating prevents the eggs from separating naturally. The time during which this should take place would be, approximately, within the first 30 minutes after they are taken, and as the boats are out from 5 to 24 hours or longer, when shore is reached the time is long past when quiet is of any value. Besides, the temperature often falls far below freezing, and all the precautions that can be taken will not prevent a considerable percentage of the eggs becoming chilled, although there may be no ill effects discovered until after they reach the hatchery. Other losses often occur through accident and the carelessness of those handling the cases while en route to the hatchery. Taking everything into consideration, it may be considered excellent work if an average of 70 per cent of eyed eggs and fry is turned out. In exceptional cases as high as 90 per cent have been hatched.

COLLECTING LAKE-TROUT SPAWN ON FISHING STEAMER IN LAKE MICHIGAN.

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THE HATCHERY.

The hatching-trough or tank in use at Northville combines the principles of both the Clark and the Williamson hatching apparatus and is therefore called the Clark-Williamson hatching-box. It possesses more advantages than any other in use for the development of a large number of eggs; a thorough circulation is obtained for thousands, the apparatus is simple, and the eggs may be readily handled for picking, cleaning, etc. It consists of a trough of any length according to the number of fry to be held, 18¾ inches wide inside and 1 foot deep, with partitions to divide it into compartments, and is constructed as follows: Only the best 1½-inch pine is used, all planks containing knots, heavy pitch, etc., being rejected, and the sides and ends are each made of but one piece of lumber. The bottom is made first, the strips of different widths plowed and tongued securely, and all joints laid in white lead.

Referring to figs. 1 and 3, page 98, three-quarters of an inch down from the top of the sides is a ⅜-inch groove (A) running the entire length of the trough. The partitions, dividing the trough into compartments, 18¾ inches by 9¾ inches by 12 inches, are mortised ¼ inch in the sides; the first and each alternate partition (B) is fixed ½ inch from the bottom of the trough to allow the water to pass under it; the second and each alternate partition (C) is mortised into the bottom, and at the top is cut out so as to leave a space 14¾ inches long by 1½ inches deep for the water to pass over. In the bottom of the boxes thus formed a ½-inch strip (D) ⅞ inch wide is nailed to the sides; upon these the bottom trays rest. A crossbar (E), with ⅝-inch block (F) to hold the trays securely in place and prevent them from rising in the water, is made to fit in the grooves at the sides of the trough.

The capacity of the troughs may be doubled by the addition of a second row of boxes, one side of the first tank acting as a partition between the two rows. Each box holds eleven trays (G). Ten of these are filled with eggs, the eleventh, or top one, acting merely as a cover to prevent the eggs on the tenth tray from being carried off by the current. The trays are made of ⅙-inch mesh galvanized wire cloth, tacked upon frames 16 inches long, 7 inches wide, and ¾ inch thick. Both the trays and tanks are given three coats of asphaltum paint before being used, and one coat at the beginning of each succeeding season. Eleven of such trays, in the box described, will fill the compartment to within ⅝ inch of the groove in the sides of the tank; then the crossbar with the ⅝-inch feet holds them securely in place. The tanks are set upon iron standards cemented in the floor, and are given a pitch of ⅛ of an inch to the foot. The height of the tank from the floor is a matter of convenience to the operator, depending on the fall of water available.

The water enters through a 1-inch pipe at the head of the tank, flowing down through the first division, up through the second, and so on to the lower end. Where water is scarce, two troughs may be made to

utilize the same supply by placing one after another, the upper end of the lower trough being from 8 to 12 inches lower than the overflow of the upper trough; this gives a good aeration and will be found to answer

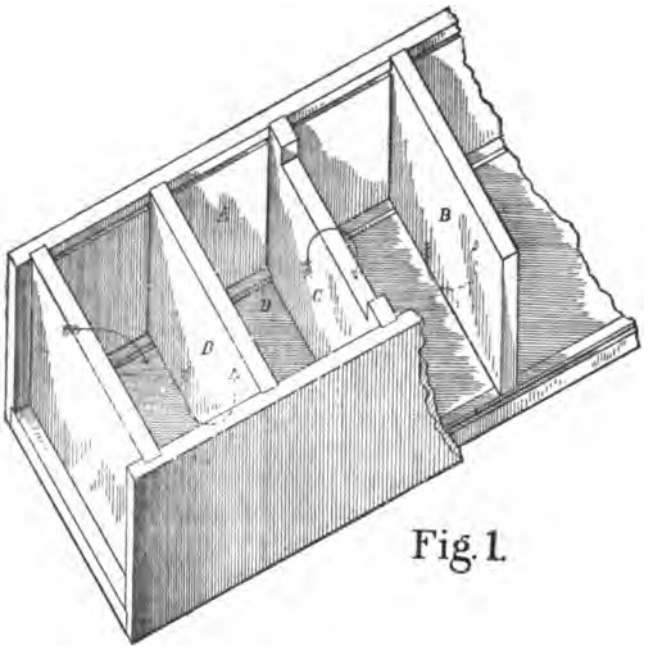


Fig. 1.

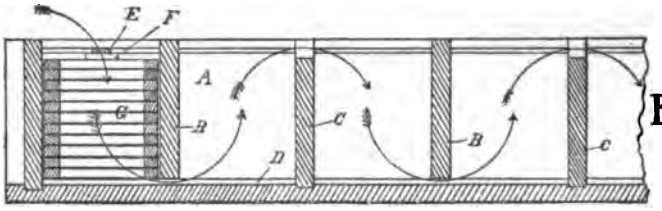


Fig. 2.

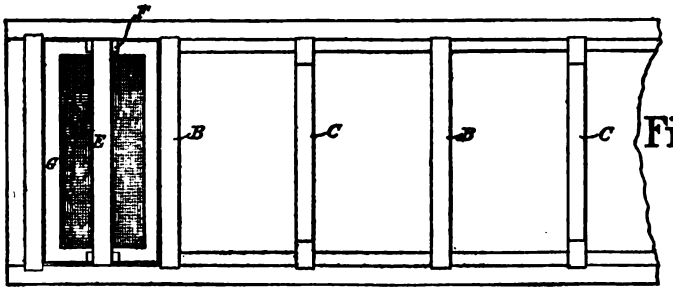


Fig. 3.

Clark-Williamson Trough.

nearly as well as though fresh water was conducted to the tank. Should the supply be taken from a creek, lake, or other reservoir exposed to changes of weather and drainage from the surrounding land,

or if it abounds with aquatic insects, it is quite essential to have some kind of filtration, otherwise the eggs may be injured by animalculæ or coated with sediment, the trays clogged with refuse, the circulation stopped, and in the end a majority of the eggs lost. Many filters have been devised, all of which are good, but a simple and effective contrivance is made by tacking medium-weight flannel to wooden tray frames and placing them at the head of the tank directly beneath the head of water, the number used at one point being governed by the amount of sediment or other foreign matter present.

At Northville, as a convenience in caring for eggs, a shallow "picking-trough" is used, 40 feet long, 10 inches wide, and 2½ inches deep, with a ½-inch strip, ⅞ of an inch wide, nailed along each side of the bottom, upon which the trays rest, to give a good circulation while the eggs are sorted over. The trough has a fall of not more than ½ inch throughout its entire length, and it is fed by a flow of about 2 gallons of water per minute. A dam at its lower end raises the water 1¼ inches, not entirely covering the trays. This is a point that must not be overlooked, for if the water flows over the tops of the trays many of the eggs and fry will be apt to escape through the waste-pipe.

CARE OF THE EGGS AND FRY.

Upon their arrival at the hatchery the eggs are taken from the shipping-cases and turned into tubs, whence they are removed to the hatching-troughs. In removing eggs from the flannel shipping-trays to the tub the same method is followed as in washing eggs that have been held in cases for several days. The transfer should take place in a temperature not higher than 45° or 50° F., and if the eggs are held in the tubs for any length of time they are given a change of water every 30 minutes.

Great care is necessary in transferring eggs to the hatching-trough in pails. To guard against any shock, the pail is partially filled with water, and the eggs are carefully taken in the dipper, which is lowered into the pail in such a way that the eggs will glide into the water and not fall upon it. The pail when filled is placed upon the trough as near as possible to the box for which the eggs are intended, and by means of a perforated dipper with a capacity of 20 ounces, or 4,000 eggs, they are transferred to the hatching-boxes. A tray is placed in the water and a dipperful of eggs is poured upon it; then another tray, placed on top of the first, is served in like manner, and this is repeated until ten trays are filled. The eleventh, or cover tray, is left empty, and the whole apparatus is held in place with a crossbar or binder. In two double troughs, containing 64 boxes and occupying a floor space of 106 square feet, 2,560,000 eggs may be safely carried with 22 gallons per minute of good spring or lake water, well aerated.

To estimate the number of eggs laid down, a fractional portion of a quart is counted several times until a satisfactory average is arrived at; this has given 200 to the fluid ounce, or 6,400 to the quart.

For the first few weeks after the eggs have reached the hatchery close attention must be given to prevent the growth and spread of fungus throughout the tank. The eggs must be carefully hand-picked, and the trays and boxes kept thoroughly cleansed from slime and other impurities. If a heavy rain should wash dirt, refuse, etc., into the supply reservoir and thence to the hatchery, the eggs must be cleaned to prevent their smothering. No filter, practical for use in a hatchery, has been invented that will entirely remove injurious substances.

To remove the egg-trays from the boxes for sorting, the binder is first slipped out from the grooves and the trays taken out separately, each rising to the surface as the one above it is removed. All the trays are taken out of one box and placed one after another along the picking-trough. The dead eggs and "ringers"—the latter not appearing until in the later stages of incubation—are then picked out with small metal tweezers. The eggs will turn white when dead, and if allowed to remain upon the trays a fungus will soon appear upon their surface and spread its growth until all the eggs within a short radius are affected; these in their turn will be smothered and become fungussed in the same manner.

When it is necessary to change the position of the eggs in order to bring those at the bottom to the surface a soft feather is used, and if manipulated carefully it will have no injurious effect. After the eggs have been carefully sorted the trays are again placed in the hatching-box. The eggs are looked over at least every three days during the first five or six weeks; at the end of that time, in a water temperature of from 40° to 45° F., the eye-spots will show up plainly, and from this stage to the breaking of the shell less labor need be expended in this direction, for the eggs are not so susceptible to fungus, etc., as in the early stages. At this period unimpregnated and imperfectly developed eggs are easily distinguished and taken out at one picking, leaving practically only those that will ultimately hatch as perfect fry.

For washing the eggs when coated with sediment a large galvanized-iron pan, about 2½ feet long, 1¾ feet wide, and 4 inches deep, is used; this is nearly filled with water and a tray floated on its surface. The eggs are gently moved about with a feather, and by submerging and quickly raising the tray the eggs will be left as clean as when first taken. It is necessary to be very careful to give no sudden jar or shock to the eggs, for up to the time the eye-spots begin to appear they are very delicate and must be handled accordingly. It is better to allow a small amount of dirt to remain on the eggs than to undertake washing them, which should only be done when the coating of sediment becomes dangerously heavy. The boxes may be washed when the trays are in the picking-trough, but to wash the trays is difficult, yet very necessary in case they become covered with slime.

The eggs may be transferred to a clean tray without serious harm by placing the clean tray face downward upon the dirty one, and by a quick movement reversing their positions, submerging both trays in a

pan of water. This will deaden the fall of the eggs from one tray to the other and free what few adhere to the first tray.

In a water temperature of from 40° to 45° F., hatching will begin in from 75 to 90 days. The dark hue of the egg as a whole, the distinct outline of the fish, and its convulsive movements show the approach of the hatching period. If the weather is clear and cold these indications may continue for some time, but with the advent of a single warm day more than 50 per cent of the fry are apt to break their shells.

As the total number of eggs received at the hatchery has decreased, in order to determine the number of fry that will be hatched they are now measured again by first emptying the eggs in the large pan described above, and then placing 4,000 each upon trays, in this case made of wire cloth with a $\frac{1}{11}$-inch mesh. Should the temperature remain uniform the hatching will cover a number of days, but a sudden rise or fall in the temperature will have a marked effect in either advancing or retarding the further development of the eggs.

The dead shells from the hatching fish must be removed or they will clog the trays and stop the circulation of water. To provide against this, one box of trays is emptied into a pan of water and the eggs stirred with a feather; the shells rise to the top and can be easily poured off, and by repeating this operation several times the hatching fish are entirely freed from this refuse. In returning the fish and eggs to the trays they should be divided as equally as possible among the ten trays. The necessity for this depends on the rapidity of hatching and perhaps a single box need be served in this manner only three or four times during the hatching period.

The care of the fry from this time to their distribution, if distributed before the absorption of the food-sac, is somewhat similar to the treatment described for eggs. Monstrosities, "blue-sacs," and dead fry are picked out as soon as they are discovered. The yolk-sac attached to the fry will be gradually absorbed and the fry so increase in size that 4,000 overcrowd one tray, and when the sac is about half gone, which is in about three or four weeks after the fish are hatched, it is necessary to reduce the number upon each tray to 2,000.

DISTRIBUTION OF THE FRY.

Lake trout should either be planted while the food-sac is still visible, or not until they possess the vitality of the yearling. Trout planted when the food-sac is within one or two weeks of complete absorption have sufficient nourishment to sustain life until they are acclimated to their surroundings, as well as the natural impulse from the beginning to take the minute particles of food which they find. As from 2,000,000 to 4,000,000 lake trout are hatched at Northville annually, it is impossible, with the present facilities, to hold them all in rearing-troughs and ponds until they become yearlings, and the fry are usually distributed direct from the hatching-boxes.

In shipping them to their destination, 10-gallon round-shouldered cans are filled to within a foot of the top with the water used in hatching. One trayful, or 2,000 fry, is put in each can, and as soon as it is filled, enough ice is added to bring the temperature down to 38° or 40° F. If the fry are to be planted in the Great Lakes, the cans are transferred from the car, upon its arrival at its destination, to a fishing-tug and conveyed to the reefs or natural spawning-grounds of the lake trout; here the cans are lowered into the water and the fry allowed to escape and in a few moments they disappear from the surface and sink to the bottom.

PACKING EYED EGGS FOR SHIPMENT.

When the eye-spots are plainly visible, the eggs can be packed and successfully shipped to any part of the world, if kept at a uniform temperature. The trays used for this purpose are made like those used in shipping green eggs from the field station to the hatchery. For 100,000 eggs 16 trays, 18 inches by 18 inches, are required; for 50,000, 8 trays, 16 by 16; and for 5,000 eggs, 5 trays, 8 by 8. After they are packed, the trays are placed one upon the other and crated together by nailing a cleat on each side from the foundation to the top board. The packing-case is made large enough to admit of an air-space of 4 inches around the top, bottom, and four sides of the crate, when it is placed in position. Rope handles are inserted at the sides.

The temperature of the packing-room should not be higher than 40° nor lower than 26°. A temperature of from 28° to 30° is preferable. The canton-flannel trays are first soaked in water, drained, and then placed upon a table to receive the eggs. Wooden frames of ¾-inch square strips, made so as to fit inside the frames of the packing-trays, are then inserted. A box of eggs, previously picked and cleaned, is taken out, drained, and carried to the packing-room. The eggs are carefully brushed from the wire trays upon the flannel trays with a feather and spread evenly over the surface. To divide the eggs among the flannel trays is not difficult, as there are 40,000 in the hatching-box, or 4,000 to the tray. The inner wooden frame is now removed, leaving a ¾-inch margin on all sides between the eggs and the tray frame, and a piece of damp mosquito netting is laid over the eggs, extending 1½ inches beyond the sides of the frame. This netting is pressed down at the inside corners of the tray and all along next to the frame, in order to hold the eggs in position and avoid their coming in contact with the wooden frames. Over this netting is scattered sphagnum moss, ½ to ¾ of an inch deep. This moss is gathered in the fall, and is prepared by being soaked in water and wrung out with a clothes-wringer. It must be free from all sticks and decayed matter and thoroughly wrung out, picked apart, and made fluffy, for if used upon the eggs in a compact mass, the supply of oxygen would not be sufficient for their maintenance while en route. It should be moist, but not so wet as to drip on the eggs.

When packed the egg-trays are placed upon a foundation-board, made the same size as the trays and covered with moss. At the top another board of the same dimensions is laid. Cleats are nailed on all four sides and fastened to the top and foundation boards, making a firm crate, which can be handled without danger to its contents.

If the temperature of the packing-room is not below freezing, the trays are placed out of doors before they are crated, to allow the moss upon the eggs to become slightly frosted. Eggs at this period may be subjected to a very low temperature without injury—in fact, may be enveloped in a thin coating of ice, and if shipments are made when the weather is too warm for frosting the results are not so good.

A packing-case, provided with rope handles, is prepared large enough to admit of an air-space of 4 inches around the top, bottom, and four sides of the trays. The bottom is filled 4 inches deep with fine shavings, the crate of eggs is placed upon them, and more shavings packed all around between the trays and the case. The packing is carefully done, a few shavings being thrown in and pounded down before more are added, in order that the trays may be held securely in the center of the case. Shavings are filled in on top, the cover screwed on, and the box is ready for shipment.

In transit the eggs must be kept in a cool place, though not allowed to freeze; and if this precaution is taken, and they are not unnecessarily jolted, they will be found in good condition when unpacked. Hundreds of thousands of eggs have been thus shipped from Northville during the past few years, the eggs arriving in fine condition and with practically no loss.

For foreign shipments a double box is used. The inside one is made 2½ inches larger on all sides than the crate of trays, and the outside one large enough to make a 5-inch space on all sides when the smaller box is placed within it. The trays of eggs are prepared as in ordinary shipments, and, when crated, are placed in the smaller box upon a frame which is constructed from a ⅛-inch strip, 2½ inches wide, tacked at right angles to the inside and bottom of this box. In the space thus formed between the crate and the box is packed finely chopped ice, water from the melting ice being drained off through a half dozen small openings in the bottom of the box. This box is now packed according to the same plan as that followed with shipments for a short distance. Where there is an opportunity it is advisable to have the case unpacked while en route and fresh ice added. Eggs have been shipped in this manner to England, Mexico, New Zealand, Japan, and South America, and have reached their destinations with little loss.

FEEDING AND REARING LAKE TROUT.

Lake trout fry held for rearing are kept in troughs until they are large enough to be transferred to ponds. These troughs at Northville are 12 feet long and 2 feet 7 inches wide, with a 1-inch partition running through the middle its entire length, thus forming two troughs, each

1 foot 2 inches wide. At intervals of 18 inches, cleats 1¾ inches high are mortised across the bottom, and in the sides of the trough, at the ends of the cleats, grooves are made to admit the placing of a fine-meshed vertical screen, which can fit tightly to the partition at the bottom. Everything is coated with asphaltum paint. The trough has a fall of one-fifth of an inch to the foot, the overflow being at the end through a tin spout. Another trough may be set at the lower end of the first, provided, as with hatching-troughs, a sufficient fall is given for aeration.

A week or ten days before the disappearance of the yolk-sac, which will be absorbed in five or six weeks, with water at a temperature of 40° to 45°, the fry intended for rearing should be transferred to the troughs. In a single trough of the size described, 15 gallons of spring water per minute, with a temperature ranging from 45° to 50° F., will support 8,000 fry during the first few weeks they are held. Up to this time it is not necessary to insert the vertical screens except at the head and outlet, but as the fry increase in size they become restless, snapping at each other and crowding together in a mass at the head of the trough, and then it is necessary to thin them out and separate them by subdividing the troughs, holding an equal number of the fry in each of the compartments. The action of the fish determines when this should be done. The use of warm water hastens the development of the fry, the same as it does with the eggs.

For the first four weeks the fry are fed four times per day on finely chopped beef liver, ladled through a close screen to remove all lumps. The liver is diluted with water and the mixture fed to the fry with a feather. For some days they do not appear to take their food, but the routine is continued, and as soon as the sac is entirely consumed they commence feeding. No rule can be laid down prescribing a definite amount of food, but the fry are fed till their appetites are appeased and every fish has obtained a morsel. Some days they display more hunger than usual, a warm day especially increasing their appetites. After they begin to feed well the liver may be given to them but three times a day, more being thrown in at a time.

The troughs must be cleaned out daily by turning on an additional supply of water—not so much that the fish will be carried against the screen—and the foul matter stirred up from the bottom with a feather and worked through the wires with a small sponge. Twice a week the sides and bottom are sponged off.

Three months after being transferred to the feeding-troughs, trout will take food well and be from 1 to 2 inches long. They are then ready to go outside to the rearing-ponds. These ponds are about 32 feet long by 5 feet wide, with from 10 to 20 inches of water, and have a minimum water supply of 20 gallons per minute. The bottom is graveled and the sides constructed of planks or cobblestones, and on the sides where the sun strikes the warmest during the day a board shades the trout

from the direct rays. A pond of this description will accommodate 10,000 lake trout three or four months old. As they increase in size this number may be diminished, a great deal depending upon the quality and temperature of the water.

The temperature of the water should never be higher than 65°; preferably from 48° to 58°.

As when kept in rearing-troughs, the fish are now fed the amount they seem to desire, being neither overfed nor starved. The liver, not so finely chopped as before, is thrown in with a spoon. At the first feeding the fish may be somewhat wild and scatter over the pond, but after one or two days they will collect at one point and take the food greedily. After four weeks' time they are fed only twice per day, and as they increase in size, coarser liver is given to them. Food is thrown in slowly, and no more given at one time than the fish can eat, for waste matter soon becomes foul, and unless drawn off will speedily cause sickness.

In from 10 to 12 months after hatching, lake trout artificially reared measure from 4 to 8 inches in length and are ready for planting. This is done in the same manner as with fry, 100 fish being placed in each can for transportation.

DISEASES.

The diseases to which lake trout are susceptible are those common to all other trout. They are caused by impure water, poor food, injuries received, and the attempted cannibalism of their neighbors. The first three of these causes can be guarded against, but the last is much more difficult to prevent. At the first sign of cannibalism the fish must be thinned out, and, if feeding well, transferred to the rearing-pond, where they will have greater range for development. In fact, for any of the diseases this will prove of more benefit than anything else.

It is beneficial to treat the fry with salt twice a week by shutting off the water and sprinkling salt in the trough until a weak brine is formed. The fish must be watched closely, and as soon as they show any signs of "turning up" a full head of water must be turned on until all the brine is washed off, after which the supply may be reduced to the regular amount. A small quantity of swamp earth should be scattered in the tanks about once in two weeks, merely enough to discolor the water for a few moments, and allowed to wash off gradually with the current of the water.

THE GRAYLINGS.

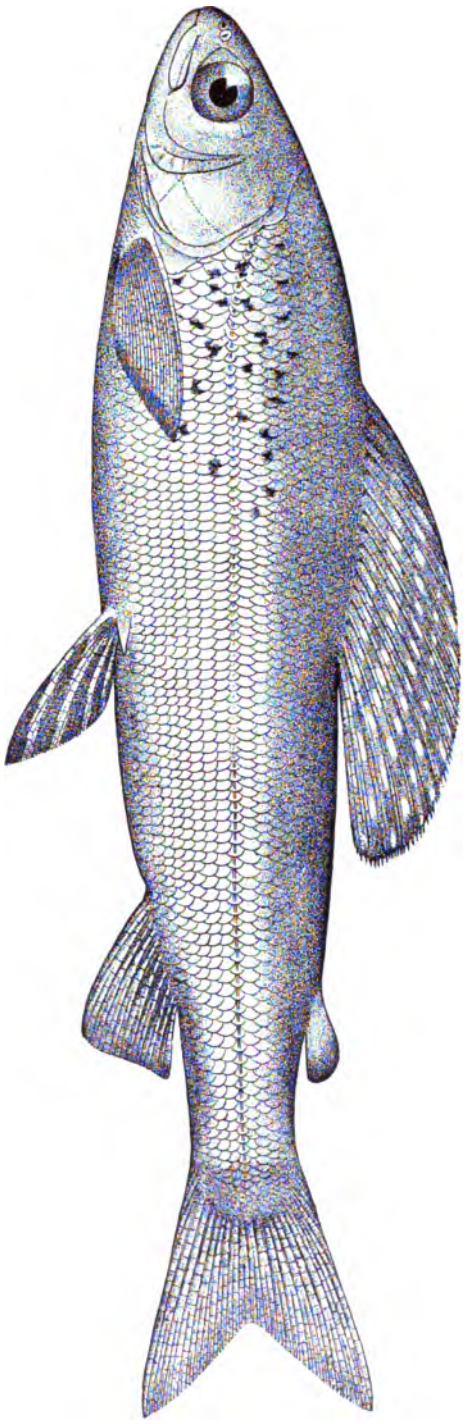
The graylings of America comprise *Thymallus tricolor* of Michigan, *Thymallus tricolor montanus* of Montana, and *Thymallus signifer* of Alaska and the Mackenzie River region. They are closely related to the *Salmonidæ* in habits, general appearance, etc., but differ in the character of the skeleton.

Only the Montana grayling at present receives the attention of fish culturists. Its body is elongated, compressed, the depth contained 4½ times in the length. The subconic head is of moderate size, and its length is one-fifth that of body. The dorsal outline, from snout to tail, is a uniform gentle curve, highest at the beginning of the dorsal fin. The mouth is oblique, terminal, and of moderate size; rather feeble teeth, of uniform size, occur on jaws, palatines, and vomer. The short and stiff gillrakers number 17. The eye is large, exceeding length of snout, and is contained 3½ times in length of head. From 82 to 85 scales are found along the lateral line, with 8 rows above and 10 rows below the line. The dorsal fin is long and high, and contains 18 to 21 rays; both its length and height equal the depth of body. The caudal is strongly forked. The coloration is gorgeous. The color of the back is gray with purplish reflections; the sides of head and body are lighter, with purplish and silvery iridescence; the belly is pure white; there are a few V-shaped black spots on the anterior part of the body; a dark heavy line, most distinct in males, extends along upper border of belly from ventral to pectoral fins. The dorsal fin is richly variegated with a rosy border, 4 to 6 rows of roundish rosy spots in whitish areas, with dark blotches forming lines between the spots. The ventral fins have three rose colored branching stripes along the rays. The anal and pectoral fins are plain, with dark border.

The Michigan grayling is generally similar to the foregoing, but has a somewhat larger dorsal fin and slightly different coloration. The Arctic grayling has a higher dorsal fin, with 22 to 24 rays, a smaller head (5½ in length), and more brilliant colors; the back and sides are purplish gray, the belly blackish-gray with irregular white blotches, and the head brown; on the anterior part of the body are 5 or 6 deep-blue spots, and on each side of lower jaw a blue mark; the dark-gray dorsal has pale blotches and cross rows of rich blue spots edged with red; the ventrals show red and white stripes.

The Michigan and Montana graylings rarely weigh 1½ pounds, and average only ½ pound; the northern species is somewhat larger.

The Michigan grayling is naturally found only in certain streams in Michigan, although the type specimen was said to have come from Lake Ontario. It is one of the most attractive and gamy fresh-water



THYMALLUS TRICOLOR MONTANUS. *The Montana Grayling.*

THE GRAYLINGS.

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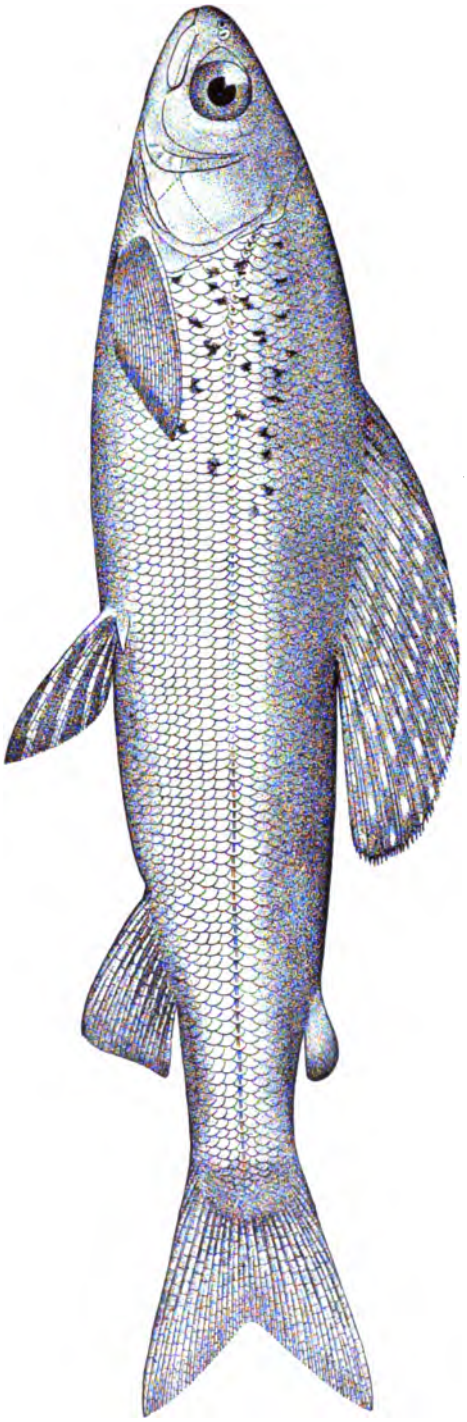


THYMALLUS TRICOLOR MONTANUS. *The Montana Grayling.*

fishes, but is rapidly approaching extinction, owing to excessive fishing and the pollution of streams.

The Montana grayling exists only in streams emptying into the Missouri River above the Great Falls, principally in Deep or Smith River and its tributaries, and in the three forks of the Missouri, the Jefferson, Madison, and Gallatin rivers, and their affluents. It prefers clear streams of pure water with sandy and gravelly bottoms, though it occasionally extends its range to those well strewn with bowlders and broken rocks.

The Arctic grayling (*Thymallus signifer*) is found from the Mackenzie River westward through Alaska and north to the Arctic Ocean.

The Michigan grayling spawns in April and the eggs are normally laid in gravel beds in clear, cold streams, in water having a temperature of 50° to 60° F. The incubation period is 14 to 20 days.

The spawning season of the Montana grayling is in April and May, depending largely on the temperature of the water. In the north fork of the Madison River the water is comparatively warm, and the grayling spawns a month earlier there than in other waters of Montana. In connection with the hatchery of the Commission at Bozeman, an egg-collecting station has been established on Elk Creek, one of the feeders of Red Rock Lake, where the fish are taken in a trap as they ascend to the spawning-beds. They will proceed long distances to find suitable spawning-grounds. At the approach of the season they go up the Jefferson, through Beaver Head and Red Rock rivers, to Red Rock Lake, 14 miles in length, and through the lake to the inlets at its head. After spawning they return through the lake to the rivers below, none stopping in the lake, which is totally unsuitable for them. At spawning time Elk Creek is fairly alive with grayling on the gravelly shallows, where their large and beautiful dorsal fins are to be seen waving, clear of the water, in the manner of shark fins on a flood tide. So eager are they to ascend that they would be smothered in the trap were they permitted to enter at all times, and the trap is therefore opened only for a limited time during the day.

Although the cultivation of the Michigan grayling was undertaken as early as 1874, it was never regularly or extensively conducted. The artificial propagation of the Montana grayling was begun at Bozeman in 1898, and in 1899 5,300,000 eggs were taken and 4,567,000 fry were hatched and liberated. The number of eggs varies from 2,000 to 4,000 to a fish, averaging 2,500 to 3,000. They are about 0.14 inch in diameter, and run from 750 to 840 to a fluid ounce. The eggs in the ripe fish lie loosely in the abdominal cavity, and the fish is quite easily stripped.

The eggs are fertilized by the dry process and fully 95 per cent are fecundated. When first extruded they are perfectly free and separate, and are of a rich yellow color owing to the presence of a large oil-drop which makes them almost semi-buoyant; after a few days they become almost colorless and as clear as crystal. If placed on ordinary flat trays, crowding each other and exposed to a lateral current of water, the eggs adhere in bunches, and fungus soon appears, entailing much labor in picking and a great loss of eggs. The embryo becomes very

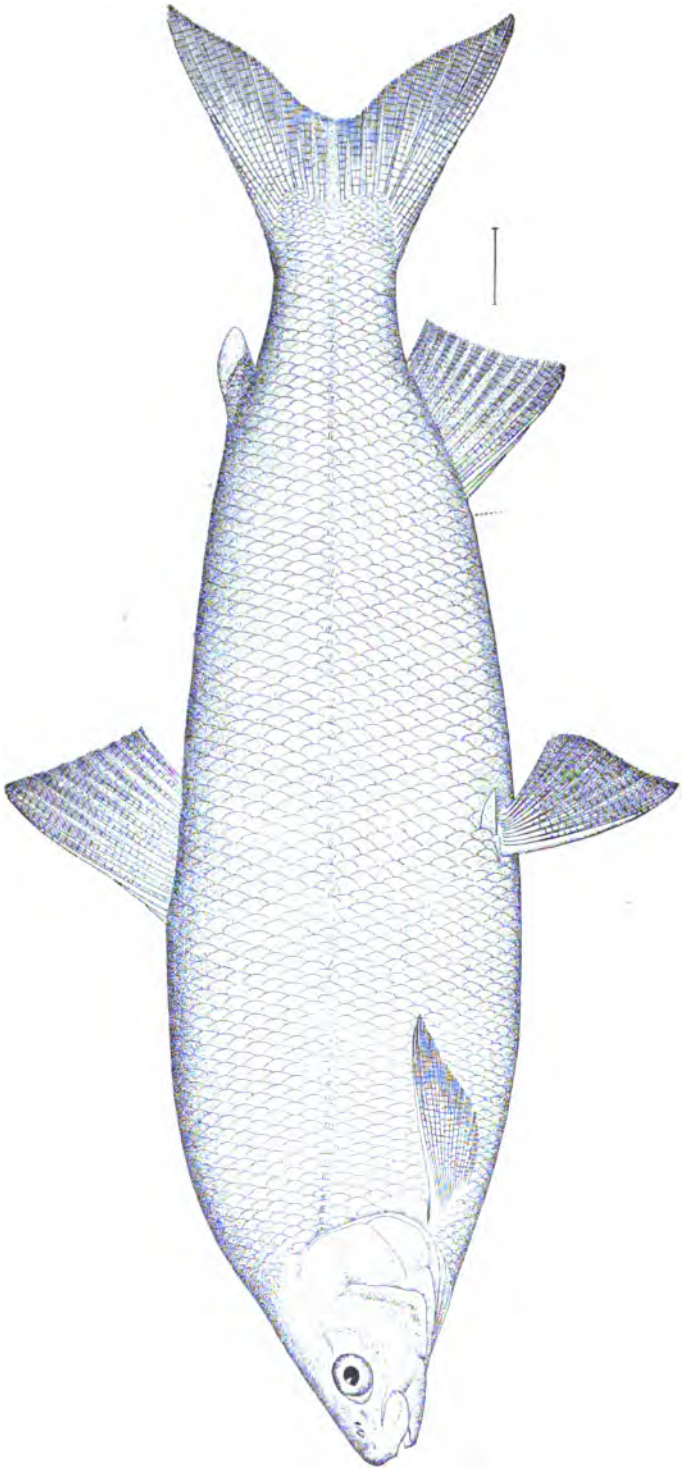
active before the eye-spots appear, and the eggs are apt to float off from the trays. For these reasons they should be eyed in hatching-jars, preferably, or in baskets in troughs, such as are used for hatching salmon where the current of water or pressure is from below. After the eye-spots appear the eggs are heavier and can be hatched like trout eggs, on ordinary flat trays. The eye-spots are small gilt specks with a minute black pupil, and appear in from 3 to 5 days. The period of incubation is from 10 to 15 days at a temperature of 50° F. When first hatched the fry have a very small yolk-sac, which is absorbed in about a week, when they become free-swimming animals about half an inch long and quite slender and delicate, resembling the fry of whitefish or shad.

Finely ground liver is the best artificial food for grayling fry; this they take very well. Dry or floating food has been tried, but without success. Baked liver, ground very fine, fish cake, yolk of hard-boiled egg, corn meal, etc., were given a fair trial, but all were refused except the powdered yolk of egg, which was eaten sparingly; beef chopped fine and rubbed through a sieve was also refused. An examination with the microscope shows that the fry have two sharp, retrorse teeth in the upper jaw, similar to those in the fry of the lake whitefish. This would indicate that their natural food is minute animal organisms, and experience at the station has confirmed this supposition. Such food is not found in spring water, which, moreover, is usually too cold for the delicate grayling fry. It has also been found that after feeding for a week or ten days in the hatching-troughs containing spring water with a temperature of 45° F. they began to die from the lack of warmer water, sunshine, and their natural food.

As soon as the fry begin to swim, and before the yolk-sac is entirely absorbed, they should be transferred to shallow, sunny nursery ponds, with a deep current and supplied with creek water with a temperature of 60° to 65° F. At this period they have been kept alive in a jar of still water, without change, for four days, showing that they could be successfully transported in cans for planting, at this age. Unlike trout fry, which seek the shade, grayling fry keep on the sunny side of the ponds. They begin foraging for natural food as soon as placed in the ponds, and are extremely active. If the water contains plenty of natural food, they will do well, but at first they are fed at least six times a day.

The usual method of packing trout and salmon eggs for transportation will not answer for grayling eggs, which will not bear crowding or pressure. The egg trays must be quite shallow, the frames not over ½ inch in depth, with a cotton-flannel bottom tacked on tightly. The eggs are placed in a single layer, covered with damp mosquito netting. The temperature must not go above 45° F., and should be kept lower, if possible, by packing ice with moss or shavings on all sides of the stack of trays in the egg case. The ice hopper on top is of uniform area with the trays, with perpendicular sides instead of the usual flaring sides, to facilitate reicing during the journey. Packed in this way, and the temperature kept about 40° F., to retard the development of the embryo, grayling eggs may be carried any distance desired.

PLATE 33.



COREGONUS CLUPEIFORMIS. *Common Whitefish.*

THE WHITEFISH.

DESCRIPTION, COMMON NAMES, ETC.

The common whitefish (*Coregonus clupeiformis*) is eminently a lake fish. It exists throughout the Great Lakes region, and is especially abundant in lakes Erie, Huron, Michigan, and Superior. The eastern limit of its range is Lake Champlain, and it is found in Lake Winnipeg, and possibly farther west. It is landlocked in Otsego Lake, New York. Efforts to introduce it into new waters in the States of the Pacific Coast and Rocky Mountain region have not as yet been successful.

Its body is rather long and compressed, and the back, especially in adults, is arched in front; the greatest depth is about one-fourth the body length. The head is small and short, contained about 5 times in the length of the body; the snout is blunt; the mouth is small and nearly horizontal with the lower jaw included; the maxillary is short and broad, reaching to a point under the pupil; the mandible extends to a point under the posterior edge of eye. The eye is small, its diamter being about one-fifth the length of the head. The rays in both the dorsal and anal fins number 11. The number of rows of scales along the side of the body varies from about 82 to 92, with about 11 above the lateral line and 8 below. The gillrakers number about 28, of which 10 are on the upper arm of the gill-arch; the longest are contained about twice in the length of eye. The general color of this fish is a satiny white, with a faint olive-green shade on the back. The fins are uniformly white, except the caudal, which normally has a dark edge.

This fish has a number of common names in different parts of its range. It is the whitefish par excellence of the United States and Canada. As found in Otsego Lake, New York, it is inappropriately called "Otsego bass." In allusion to its humped back it is called "highback whitefish," "bowback whitefish," "buffalo-back whitefish," and other similar names, in Lake Superior.

While more is known of the habits of this species than of any other member of the group, many phases in its life are still obscure, as it remains in deep water most of the time. Besides the regular annual movements of the schools to the spawning-grounds, there are other well-marked migrations in some lakes. Whether these depend on food, temperature, enemies, or other causes, is not known. Owing to its small, weak mouth, it is seldom taken with a baited hook. It subsists on minute animal food, chiefly crustaceans, mollusks, and insect larvæ. The food of the fry and young fish is almost wholly small crustaceans.

COMMERCIAL AND FOOD VALUE, ETC.

The whitefishes are by far the most important group of fresh-water fishes of North America, probably of the world. The common whitefish is the best of the tribe, but some of the others nearly equal it in merit, and all are more or less esteemed as food. Among the fishes of the Great Lakes the common whitefish ranks next in value to the lake herring, lake trout, and wall-eyed pike. In 1897 the catch in the United States amounted to about 8,000,000 pounds, having a value of nearly $300,000. If to this is added the yield of lake herring and other species of whitefish, the aggregate is over 57,000,000 pounds, having a value of nearly $800,000. The market value of the whitefishes taken in 1898 in the British Provinces was reported as $877,000, a sum representing about 18,400,000 pounds.

The common whitefish reaches a larger size than any other species of whitefish in the United States. Examples weighing over 20 pounds have been taken, but the average weight is under 4 pounds.

Whitefish fishing is done chiefly with gill nets set at or near the bottom in comparatively deep water, although considerable quantities of whitefish are also taken in pound nets, trap nets, and seines. A very large part of the catch reaches the market in a fresh condition, although formerly considerable quantities were salted. The leading centers of the trade are Chicago, Detroit, Sandusky, Cleveland, Erie, and Buffalo, whence the fish are shipped frozen or in ice to all parts of the country.

SPAWNING.

The spawning season of the whitefish begins the latter part of October and continues into December. At that season there is a general movement of the fish to shoal parts of the lakes, similar to the migration of anadromous fishes from the ocean to the rivers; some of the foreign whitefishes are typical anadromous species. After spawning, the fish return at once to the deeper water.

The spawning habits of whitefish confined in pens have been observed. The fish rise to the surface, occasionally in pairs, sometimes, but rarely, in trios of one female and two males, the female emitting a quantity of spawn at each rise. The males, always the smaller fish, persistently follow the female and discharge milt at the same time the eggs are emitted.

Whitefish reach maturity in the third or fourth year. A full-grown specimen deposits from 10,000 to 75,000 eggs, depending on the fish's size. A rule for determining the approximate spawning capacity is to allow about 10,000 eggs for each pound of the fish's weight. The eggs are an eighth of an inch in diameter, and 36,000 make a fluid quart. They swell somewhat after impregnation.

DESTRUCTION OF WHITEFISH SPAWN IN NATURE.

In nature the eggs of the whitefish are subjected to the attacks of many enemies for nearly five months. The mud-puppy (*Necturus mac-*

uldtus), commonly known as "lizard" or "water-dog" by the people along the lakes, is especially destructive. During the month of January, 1897, many of these animals were pumped up with the water supply of Put-in Bay station. The stomachs of a considerable number of them contained whitefish and cisco eggs, the contents of one stomach being 288 whitefish eggs and 4 cisco eggs.

Another voracious destroyer of whitefish eggs is the common yellow perch (*Perca flavescens*). The deck of a boat has been seen covered with the eggs of the whitefish and cisco pressed out of the stomachs of perch taken from gill nets the last of November on the reefs, where they had gone to feed on the eggs.

The various smaller *Cyprinidæ* and some other fishes, crawfish, and wild fowl make the eggs of fishes a considerable portion of their diet, those which require the longest period in hatching, of course, suffering most.

ARTIFICIAL PROPAGATION.

The artificial propagation of whitefish has long since passed the experimental stage and has attained a high degree of perfection. The work can be carried on with great facility, and its value is especially apparent when it is considered that under natural conditions only a very small percentage of the eggs hatch, while through artificial propagation from 75 to 95 per cent are productive. Practically all the eggs taken for hatching purposes are obtained from fish caught by the commercial fishermen, which would otherwise be lost.

The methods of culture hereafter referred to are those adopted at the Put-in Bay (Ohio) station, but these do not differ in any essential particular from those in general use.

In the fiscal year 1897–98 the United States Fish Commission hatched and planted 88,488,000 whitefish fry, and in 1898–99 152,755,000 fry were hatched and liberated in suitable waters.

HOW THE EGGS ARE TAKEN AND TREATED.

The taking, impregnating, and handling of the whitefish eggs are simple processes, but require great care at every stage. Eggs are often injured by undue haste in stripping, and many are lost by allowing them to fall too great a distance into the spawning-pan. Eggs are very delicate when first taken and before the absorption of water has made the investing membrane tense, and if roughly treated will be seen to be ruptured as viewed under the microscope. With care about four-fifths of the eggs will hatch. While scarcity of milt may lead to the non-fertilization of the eggs, the manner in which the milt is brought in contact with eggs is a more common cause of failure.

The eggs supplied by each spawn-taker should be examined daily, and if it is found that a considerable number have ruptured yolks it may be taken for granted that the spawn-taker has handled the fish and eggs roughly, and if many are unimpregnated it is evident that he did not use sufficient milt or that it was not properly applied to the eggs.

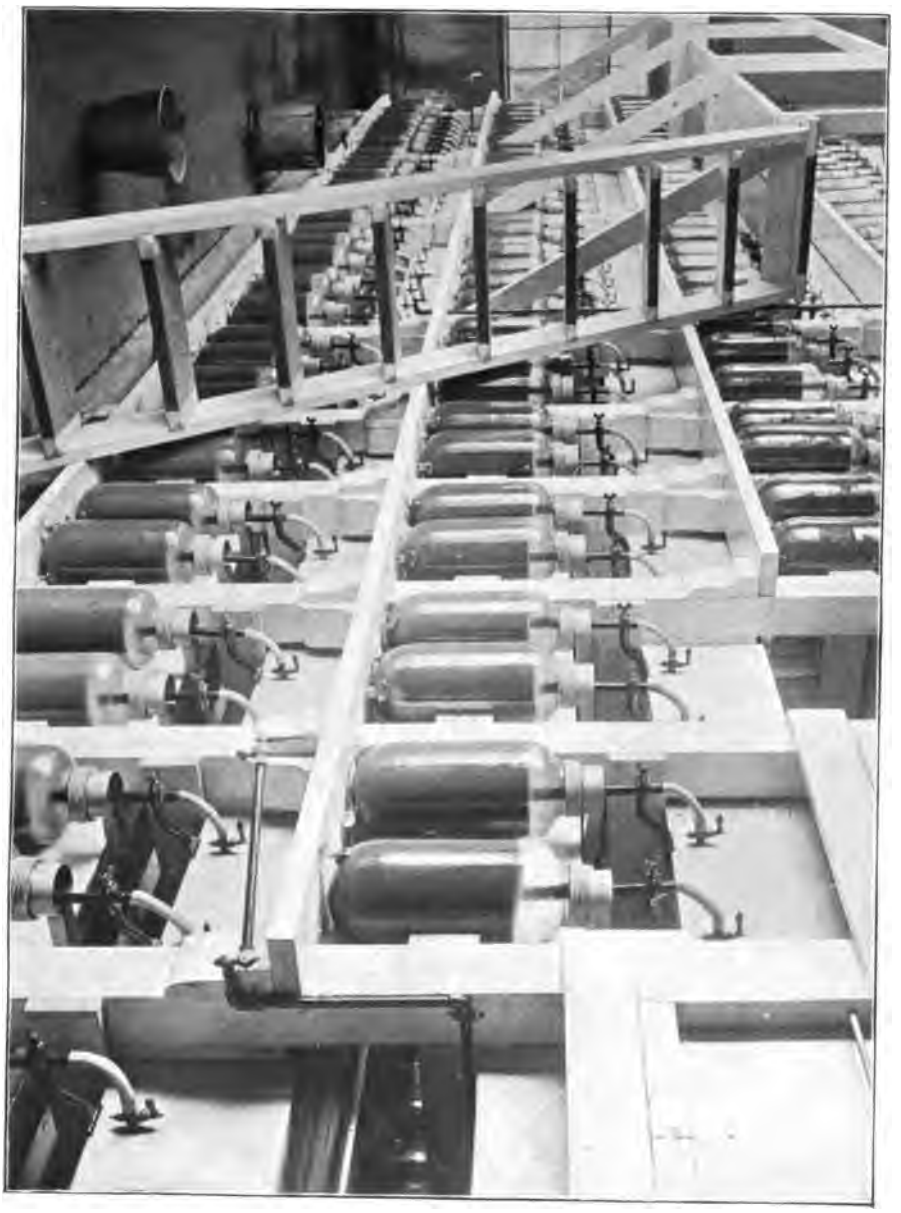
At Put-in Bay eggs are obtained from fish captured in pound nets and gill nets, often at considerable distances from the station. The spawn-taker, who is employed to take the eggs from the fish as they are lifted from the nets into the boat, has with him two or three 6-quart pans, coated with asphaltum varnish to prevent rusting, in which he takes the spawn; a wooden keg or tin can holding from 10 to 15 gallons; a 10-quart wooden pail, and a tin dipper. He is clothed in waterproof garments, and his left hand is covered with a woolen mitten for convenience in handling the fish.

After several ripe females and some ripe males are collected, a female is taken, and the body slime, which will interfere with impregnation if it falls into the pan, is carefully removed. The spawn-taker then grasps the fish firmly in his left hand, just forward of the tail, with the back of the hand downward, the fingers outward, the thumb above and pointing outward, the head of the fish being toward the spawn-taker's body. The right hand is placed under the fish just back of the pectoral fins, with the wrist pressing the head of the fish firmly against the body, the thumb outward, fingers inward, thus grasping the upper abdomen firmly. The fish is now at an angle of nearly 45°, the body forming a modified crescent, with the vent within 4 or 5 inches of the bottom of the pan. This position of the fish's body brings pressure on the abdomen, facilitates the flow of the eggs through gravity and the opening of the vent, and prevents injury to them from falling too far.

Gentle pressure being now applied, the eggs flow in a steady, liquid stream about a quarter of an inch in diameter, and a considerable portion of them will be procured before the hand need be moved. As soon as the stream slackens the hand is slowly moved toward the vent, but only fast enough to keep the eggs coming in a continual stream. When it finally stops the hand is replaced in its former position and the process repeated until all the good eggs are procured. If, as is frequently the case, when nearly all the ripe eggs are emitted a considerable number of white ones appear, the work should stop.

The dry process of impregnation is now universally considered to be the better, and the pan in which the eggs are taken is only dampened by dipping it into water before the stripping begins. After two or three females have been manipulated the milt from one or two males is added to the mass of eggs. This is done by grasping the fish between the thumb and fingers 2 or 3 inches forward of the vent and moving them toward the opening. The milt comes in a stream, an average fish producing about a teaspoonful. If ripe males are scarce the fish is laid aside, as he may be used again in a few minutes and considerable additional milt procured.

When the pan is one-half or two-thirds full of spawn and milt, the spawn-taker gently stirs the eggs to incorporate them thoroughly with the milt, using for this purpose the tail of a fish, from which the slime has been carefully removed. The pan is then partly filled with water and the mass again very gently stirred. After standing two or



HATCHING BATTERY AT PUT-IN BAY, 1899.

three minutes, the water is poured off and fresh water added, and this is repeated until the water comes away clear, when the eggs are poured into the keg or can previously filled with water, and the work of taking spawn is continued. Before adding another lot those previously put into the keg are gently stirred. It is necessary to change the water on the eggs at least once an hour, and oftener if the weather is warm, and the eggs should be gently stirred to the bottom of the keg every 30 minutes until they are placed in running water in the hatchery.

When the spawn-taker has finished he turns over the eggs to a man in charge of the field work, who cares for them until the collecting steamer comes, when they are taken aboard and transported to the station, some 2 to 5 hours having elapsed since they were taken. At the station the eggs are kept in the kegs in which they were placed by the spawn-taker and a stream of water of about 2 gallons per minute to each keg is kept running on them until the next morning, and they are stirred to the very bottom once an hour in the meantime. In this way the eggs are given time to harden with less injury than if they were immediately placed in the jars.

Formerly in shipping eggs long distances they were kept in running water in kegs, under the care of a watchman, but it has been found much better to ship them in cases on trays. After having been in water 8 or 10 hours, whitefish ova may be safely placed two or three layers deep on trays and shipped indefinite distances. If the weather is warm (55° or 60° F.) the cases must be surrounded with ice, or sawdust and ice.

In placing the eggs on the trays a perforated dipper is used and a little practice soon shows about how many to dip out for each tray, and if just enough water is left with the eggs a slight tilting of the tray will distribute them evenly over its surface. Then by setting the tray with one corner on the floor and the diagonally opposite corner raised 3 or 4 inches, the surplus water will soon drain off. This may be facilitated by slipping a thin wooden wedge between the cloth and wood at the lower corner of the tray.

In shipping a distance of 40 or 50 miles, the trays may be placed in the cases with no other protection from change of temperature than the wood of which they are constructed—an inch thickness of tray and an inch of case with an inch of air-space between—which is found to be safe in a cool car or room in a boat, but for longer distances about 20 trays are fastened together with thin strips of wood tacked to either side and placed in a large case with from 4 to 6 inches of pine sawdust well packed on every side.

After the eggs are placed on trays and drained, they are covered with a thickness of mosquito netting, well washed and left damp, and over this is packed enough damp moss to fill the tray even with the surface. If eggs are to go by express, unaccompanied by a messenger, directions are fastened to the case stating that they must be kept cool but not permitted to freeze. Whitefish eggs have been safely shipped in this way from Northville, Michigan, to Australia. If the eggs are

to be shipped a short distance—25 to 50 miles—it is not necessary to cover them with moss.

The trays used at the station are 16 inches square, outside, and are made of white pine ¾ by 1 inch, mortised together at the corners with the widest side of the strip horizontal. On the bottom of these frames heavy canton flannel is tacked, so that the nap will come next to the eggs when in use. The cloth should be stretched very taut, otherwise it will sag on being wet and dried. The tacks are put 2½ to 3 inches apart, so that in a year or so it can be retacked between the ones first driven to take up the slack. The trays are made square, as they then go into the cases either way and time is saved in packing; square cases are also more convenient in storing and in handling generally. Such a tray will hold 50,000 eggs.

If the eggs have to be retained for several days in the field, they are sometimes kept in floating-boxes adapted for this purpose. (See description of this box on p. 95.) But unless the conditions are very favorable it is far better to place the eggs on trays, sprinkling them lightly once in two or three days.

When taken from the kegs and trays at the hatchery the eggs are passed through a screen (with meshes sufficiently large to permit the passage of a single egg) in order to remove scales and other foreign substances that may be present. The screen is floated in a washtub partly filled with water, the wire netting being well submerged.

For handling eggs and fry wooden kegs are by some preferred to tin cans, as they do not subject the eggs and fry to sudden changes of temperature, their contents are easily examined, and the water is more readily poured off without danger of losing eggs. The kegs are much lighter, only cost a third as much as cans, and last longer. For shipping in wagons or by rail, however, tin cans with covers are indispensable. Kegs should be made of white pine, painted outside but not within, and hold about 15 gallons each, and should be provided with iron drop handles.

PENNING WILD FISH.

The uncertainty of the seasons and the liability of failure to obtain spawning fish owing to severe storms which occur in November, make it desirable, wherever practicable, to capture fish in favorable weather and place them in pens until ripe. After the fish are driven off their spawning-grounds by severe storms, they do not return in large numbers during the spawning season, and the only way to insure a satisfactory supply of eggs is by penning the fish.

Nets have been tried for penning, but they do not afford sufficient facilities for sorting the fish of various degrees of ripeness and the fish have to be handled too much, thus encouraging fungus growths on them and causing many to abort their eggs. Penning is best done in crates made of boards with openings sufficiently large to admit the free interchange of water. The pens are generally made about 16 feet long, 3 or

4 feet wide, and 4 to 8 or more feet deep. They should be placed end to end in two rows, some 3 or 4 feet apart with a plank walk between, for convenience in caring for them. The fish must be handled as little and as gently as possible, otherwise the eggs will form into a hard mass and never ripen. One cause of injury is the scoop net with which they must be handled; the knots and the twine are so hard that they injure the delicate scales of the whitefish, which struggles violently when taken from the water. A net made by punching suitable-sized holes in a sheet of thin, soft, flexible rubber would be yielding and perhaps cause the least injury.

HATCHING METHODS AND EQUIPMENT.

At Put-in Bay the water for hatching is obtained from Lake Erie through a pipe that extends 75 to 100 feet into the lake. Pumps elevate the water to the loft of the hatchery, where it is received into supply-tanks, whence it is distributed by the usual methods of piping. The circular supply-tanks, two in number, are about 11 feet in mean diameter, 8 feet high, and have a capacity of 5,000 gallons each. These tanks are necessary to give an equal pressure in the pipes and to provide a supply of water in the event of cessation of pumping. A gauge in the boiler room shows the height of water in the tanks.

Whitefish eggs are hatched in the McDonald jar and the Chase jar; the former is in more general use in the United States Fish Commission, although both give satisfactory results. The eggs are put into the hatching-jars by means of a dipper having a perforated bottom. The proper number to a jar is $3\frac{3}{4}$ quarts, as determined by a gauge; these will swell to $4\frac{1}{4}$ quarts, which is about the proper quantity for the jars used.

The form of the embryo whitefish can be seen in the egg by the use of a magnifying glass in from 10 to 15 days and the eye-specks and color stars in from 15 to 20 days, the time depending much on the temperature of the water. The fry being hatched, the food-sac is absorbed in from 5 to 15 days, varying somewhat with the period of incubation. If hatching is long retarded by low temperatures, the sac will be nearly all absorbed when the fry hatches.

The microscope is a great aid in whitefish culture, enabling the operator to determine the exact percentage of dead eggs and to a great extent the cause of their loss, thus allowing him to remedy some if not all the evils. For examining eggs in their early stages the microscope is placed horizontally, the eggs being held in a cell filled with water. This may be easily made by fastening two ordinary glass slides to a strip of wood an eighth of an inch thick, with a portion cut away to form a receptacle for the eggs. The wood is thoroughly saturated with asphaltum varnish, and after drying the sides should receive a thin coat, the slides being laid on and placed under pressure to dry. When dry an additional coat to the outer joints of contact will guard against possible leaks.

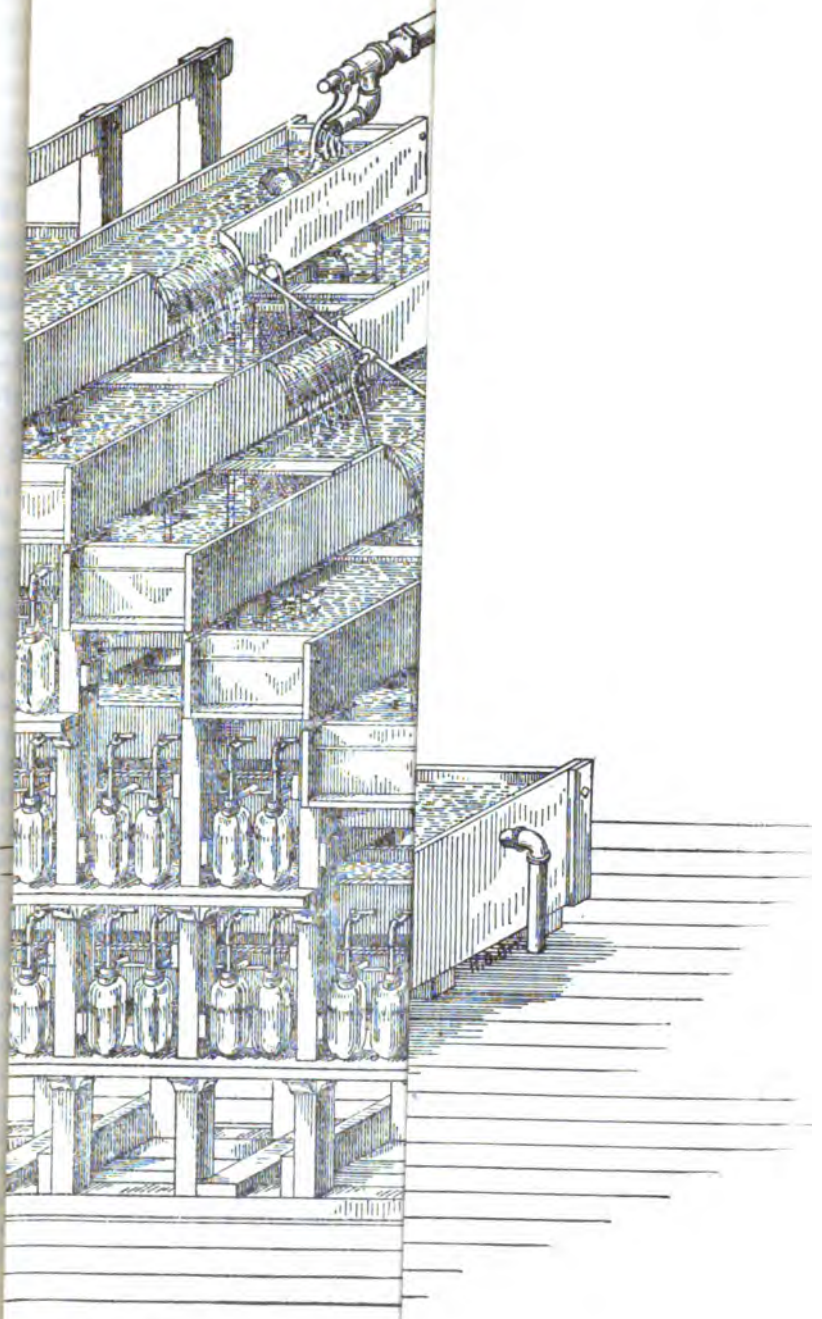
If the egg be examined 6 or 8 hours after it is fertilized, the germinal disk will be found to have contracted to a saucer-shaped cap extending over about a fifth of the surface of the yolk. It is smooth and even, gradually thinning to a sharp outer rim, with a thickness in the center of the cap of about a fifth of its diameter. At this stage—segmentation not having commenced—the impregnated eggs can not be told from the unimpregnated ones. At 18 hours segmentation will be well advanced and the disk will have contracted into six or eight rounded nodules of uneven size, with well-defined valleys between, there being no longer a sharp rim to the disk. At 24 hours—the best time to determine the percentage of live eggs—the disk presents a somewhat similar appearance, except that it will be divided into 25 or more segments, easily seen under the glass; the disk of the unimpregnated egg of the same age forms an almost exact hemisphere, is perfectly smooth in appearance, and is therefore easily distinguished from the live egg. Segmentation now goes on rapidly, and at 72 hours the cells look under a 1-inch objective—a suitable power to use in this work—about the size of a mustard seed, the disk having in the meantime assumed an hemispherical shape.

During the entire period of incubation, but more especially during the early stages of growth, the eggs should be worked as gently as possible; that is, only sufficient water should be used to keep them in slow motion and to prevent "banking." At the commencement they require about 6 quarts of water per minute to the jar, but later they will run with a quart less per minute. The eggs require constant watching for the first week or more, and although not considered an adhesive egg, agglutination takes place occasionally when the water becomes roily. Unless the "banks" so formed are separated by gently stirring them with a long feather (the long wing feathers of a turkey are suitable), the eggs forming the pack soon die and form a mass in the jar.

In a few days, varying with the temperature of the water, the unimpregnated and other dead eggs begin to "fungus"—that is, a growth makes its appearance on them and they rise to the top of the egg mass—when they must be removed by the use of a siphon, and if live eggs are among those drawn off, they must be set up in what are called "hospital jars," where the live and dead ones are more readily separated.

The dead eggs are drawn off every day, otherwise they are liable to become loaded with silt from the water and sink, mixing with the live eggs and making it difficult to separate them.

For the removal of dead eggs from the jars a long-distance siphon is used at Put-in Bay station, which saves much labor. It is constructed thus: To the short end of the ordinary siphon, which consists of a thin quarter-inch brass tube about a foot long bent into the form of a goose neck, is attached a piece of common rubber tubing 3 or 4 feet long with a $\frac{3}{8}$-inch interior diameter. This is connected with a rubber tube of the same size and long enough to reach the whole row of jars or all in the



HATCHING WHITEFISH.

house if desired. The connection is made by a thin brass nipple with the same interior diameter as the piece of rubber tube to be joined by slipping it into the longer piece and lashing it on the outside with twine, leaving about three-quarters of an inch outside to slip into the shorter piece after the siphon is started. The other end of the long tube is connected with a like piece of brass tubing, bent to a quarter circle to prevent the rubber tubing from kinking, to and through the center of a wooden float some 12 inches in diameter and 1 or 2 inches thick. This is placed in a tub or large pail; the short siphon is started and connected as above described, and the long siphon is in working order. The water runs over the rim of the tub into the sluice, over which it is placed, and the eggs settle to the bottom. A whole hatchery can be operated without moving the tub, although it is better to raise it 5 or 6 feet from the floor for the upper rows of the jars, as the suction otherwise becomes a little too strong and liable to injure the good eggs when passing too rapidly through the tube.

For convenience and for economy of space and water, the hatching jars are arranged in tiers, constituting what is known as a "battery." The structure of a battery, with its complicated system of supply and waste troughs and with the jars and their attachments, is rather difficult to describe clearly, but may be understood by reference to plate 35.

Each battery is divided into two sections, which have four rows of jars on each side, setting on shelves 3 feet apart. The water is admitted through an iron pipe to the uppermost cross-tank; from there it runs into the uppermost supply-trough, which, like all the others, is 13 inches wide and 9 inches deep, inside measurements. The iron pipe is provided with a ball-cock, regulating automatically the supply of water. The supply-troughs are from 22 to 34 feet long, the upper ones being the shortest and the lower the longest. The first supply-trough has a row of brass cocks on either side taking the water 1 inch from the bottom. A half-inch rubber tube, 6 inches long and forming when adjusted a quarter circle, is slipped over the outer end of the cock and the upper end of the iron tube, which is inserted in the jar. The water flows from this upper supply-trough, which may be called No. 1, in section No. 1, through the cock, rubber tube, iron tube, and jar, from which it is discharged into what may be called waste-trough No. 1, which is directly below supply-trough No. 1. This discharges its water into a cross-tank, the second from the top, which carries the water across to supply-trough No. 2, which is in section No. 2. This supplies the second of the eight rows of jars, through which all the water passes, and after passing through the jars, as before described, it empties into waste-trough No. 2, in section No. 2, which carries it to cross-tank No. 3, which in turn carries it across and delivers it to supply-trough No. 3, which is in section No. 1. Thus the water goes back and forth from one section to the other, dropping a step at each passage, until it finally enters the fry-collecting tank on the floor, which is 3½ feet wide, 9 feet long, and 2 feet deep.

The cross-tanks are in steps, like a flight of stairs, which accounts for the unequal lengths of the supply-troughs. Each has an overflow in the center, over which a small amount of water is kept running, so that the attendant can see at a glance that all of the troughs are full. Screens are interposed at such places in the cross-tanks that the fry discharged into them through the waste-troughs can not enter the opposite supply-troughs, but will float with the overflow successively into the lower cross-tanks down to the fry-collecting tanks.

The fry-collecting tanks, one for each battery, are connected with the main collecting tanks by means of 2-inch gas-pipe, fitted with valves, passing under the floor of the hatchery. The main tanks, eight in number, are 3 feet wide, 16 feet long, and 2 feet deep; in these the fry are retained until dipped out for shipment or planting.

The only marked difference between the method of operating the jars at Put-in Bay and other stations is the use of a ⅜-inch iron gas-pipe, instead of a glass tube, for supplying the jars with water, and the addition of a tin cone, 6 inches long and 1 inch in diameter at the lower end, which is soldered to the end of the iron pipe and reaches within one-eighth inch of the bottom of the jar. The tube is held in place by an iron bracket, fastened to the supply-trough and held by a thumb-screw. The cone has the effect of spreading the water and giving an easier and more thorough motion to the eggs than can be obtained with a straight tube.

At Put-in Bay the water passes through eight rows of jars, and the fact that the eggs in the lower rows of jars are just as good as those in the upper rows is proof of the practicability of the plan.

The jars require 6 quarts of water per minute to each jar on the top row, this amount again supplying the successive tiers of jars on the shelves below. If more jars are placed on the lower shelves than on the top one, a greater quantity of water must necessarily be added, equal to 6 quarts of water to each jar.

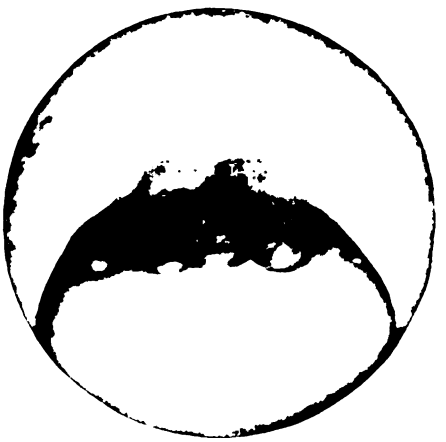
The temperature of the water must, of course, with the large quantities used, be what nature makes it, but if much above 50° F. good results can not be expected with whitefish eggs. When the work begins, early in November, the temperature of the water in Lake Erie is from 40° to 50° F., while late in the month it is generally about 35° to 38°. As soon as the lake freezes over, or ice in any considerable quantity forms, the temperature of the water as it passes through the jars remains very uniform at 32½°. When the ice goes out, which is generally about the middle of March, it rises slowly, and when the fry begin to hatch, the latter part of the month, it is generally up to about 33° or 34°.

The jars, tubes, troughs, etc., should be kept scrupulously clean. The usual coating for the inside of troughs and tanks is asphaltum varnish, but a mixture of coal tar and turpentine has proved an excellent substitute. For the first coat on new wood equal parts of each are employed; for the second and third coats one-third turpentine and

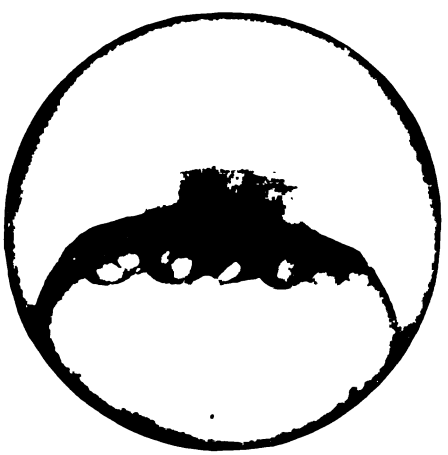
1. Unfertilized whitefish egg 24 hours old.

2. Fertilized whitefish egg 6 hours old, geminal discs forming, no segmentation having taken place.

3. Whitefish egg, 12 hours, showing first cleavage. Water 38°.



4. Whitefish egg, 18th hour. Water 38°, showing second segmentation, four cells formed.



5. Whitefish egg, 24 hours. Water 38°.

6. Whitefish egg, 48 hours. Water 38°.

DEVELOPMENT OF THE WHITEFISH EMBRYO

7. Fertilized whitefish egg 72 hours old, showing segmentation well advanced.

8. Whitefish egg, seventh day, embryo beginning to show.

9. Whitefish egg 43 days old, showing embryo.

10. Whitefish egg 90 days old, showing embryo.

11. Whitefish egg, yolk-sac ruptured by rough handling, 24 hours old.

12. Whitefish egg with triple discs.

DEVELOPMENT OF THE WHITEFISH EMBRYO

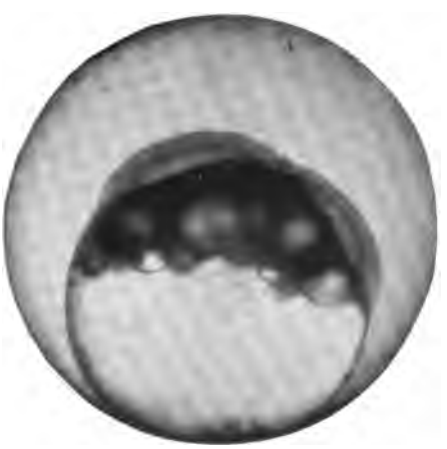
13. Whitefish egg, showing twin discs, 3 days old.

14. Whitefish egg, showing twin discs, 6 days old.

15. Whitefish egg, showing twin discs, 7 days old.

16. Whitefish egg, showing twin discs, 8 days old.

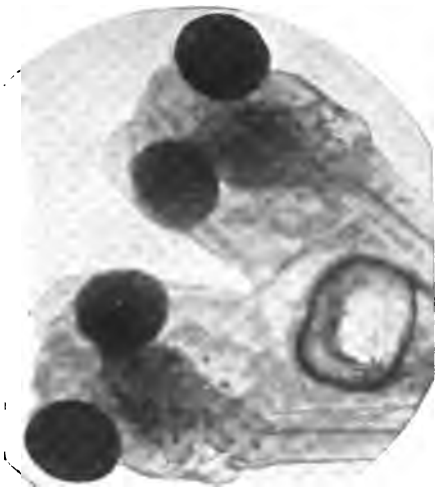
17. Whitefish egg, showing twin discs, 13 days old.



18. Whitefish egg, showing twin discs, 15 days old.

DEVELOPMENT OF THE WHITEFISH EMBRYO.

19. Double-headed whitefish fry just hatched.



20. Double-headed whitefish fry.

21. Curved spine, a common deformity of whitefish fry.

22. Whitefish fry just hatched, three-eyed, curved spine.

23. A common deformity of whitefish fry.

24 Four-eyed whitefish fry.

DEVELOPMENT OF THE WHITEFISH EMBRYO.

two-thirds coal tar. The tar should be as warm as the touch will bear, and the turpentine, which should be pure, should be added slowly while the mass is being vigorously stirred. The mixture dries quickly and forms a hard, durable surface, which is entirely waterproof and much more lasting than asphaltum; it is also much cheaper, an important item in a large station. While applying it the tin pail in which it is mixed is kept in another and larger one partly filled with moderately hot water. For pitching the cracks and joints the best asphaltum pitch is used, softened with paraffin to the consistency of chewing-gum—that is, just so that it will not break in cold water. This pitch holds firmly to the wood and keeps its place in warm weather. Other pitches which have been tried will run in warm weather and get hard with use, breaking when cold.

THE CARE AND PLANTING OF THE FRY.

When the fry hatch they immediately leave the jar and follow the course of the running water, some going through the succeeding jars, provided there are no screens interposed to prevent this, others through the overflows from the cross-tanks, until all reach the fry-collecting tank at the bottom, whence they are carried to the main collecting tanks. It has been urged by some that it is injurious for the fry to pass down through the lower jars with the complement of eggs, but in practice this has not been the case.

An air-jet on the inside of the screens will prevent clogging by the accumulation of eggshells and impurities suspended in the water. This may be easily arranged by providing an air-pump and connecting with it a pipe carried along the side of each tank on the inside of the screen and thence at right angles parallel to the screen and about an inch distant. This cross-pipe should be perforated on one side with holes $\frac{1}{32}$ inch in diameter and 3 inches apart, the holes opening toward the screen and upward at an angle of about 45°. When the air is turned on, an apparently solid mass of bubbles will arise along the whole surface of the screen. With this arrangement the screens will run hours or even days without any attention, whereas without the air-jet one or more men are employed keeping the screens clean, and many fry are unavoidably killed by being forced against the screens and by the work of the men in keeping them free. The thorough aeration of the water thus indirectly accomplished is very beneficial when large numbers of fry are passing over, and double the number can be safely handled in troughs thus equipped.

At Put-in Bay the fry are planted as soon as hatched. They are dipped from the fry tanks into kegs, in which they are transported to the natural spawning-grounds on the reefs; each keg containing 50,000 to 100,000 fry, according to the distance to be traveled. If they are to be taken any considerable distance, fresh water is kept running on them. If the facilities are such that the fry can be held in tanks until they attain a length of an inch before being planted, they would be

better able to take care of themselves than if deposited at an earlier stage. In the spring of 1896, about 1,000 whitefish fry were held in one of the station troughs until late in April, with no other food than the entomostraca and other minute life which came into the troughs with the water pumped from the lake. They grew considerably and were remarkably active. Cannibalism was of frequent though not of general occurrence; toward the close of the period through which the fry were held, numbers could be seen which had seized others by the tails and swallowed as much of the bodies as possible, which was, of course, but little. In every case one of the larger had attacked one of the smaller, the victim being dead and his destroyer swimming about actively with the body of the dead fry trailing along his side. If these fry had been regularly supplied with food, it is not probable that cannibalism would have occurred.

REARING IN PONDS.

There have been few attempts to raise whitefish in ponds on a large scale, but experiments lead to the belief that under favorable conditions whitefish can be raised in artificial ponds to some extent. Of course an abundance of good cold water, suitable ground for the construction of deep ponds, and convenience to railroad communication would be essential to success.

A successful experiment in this direction was begun at Northville in 1882. The fish were treated as young trout are, being fed wholly on liver. Three-year-old whitefish, artificially reared, yielded a large number of eggs, a fair percentage of which were fertilized. Fish weighing from 3 to 4½ pounds, that had never been fed on anything but liver, were plump and healthy. Similar successful experiments have been made in Europe with one of the native whitefishes (*Coregonus lavaretus*), and noteworthy experiments in the rearing of whitefish in ponds have been conducted by private enterprise at Warren, Indiana. It has been found that in the raising of fry the temperature of the water should not go above 55° F., and that 65° is fatal, but fish three or four months old will stand a much higher temperature.

U. S. COMMISSION OF FISH AND FISHERIES,

GEORGE M. BOWERS, Commissioner.

ARTIFICIAL PROPAGATION

OF THE

SHAD AND PIKE PERCH.

Extracted from the Revised Edition of the Fish Manual. Pages 121-145 and 165-179, Plates 40-46 and 51-52.

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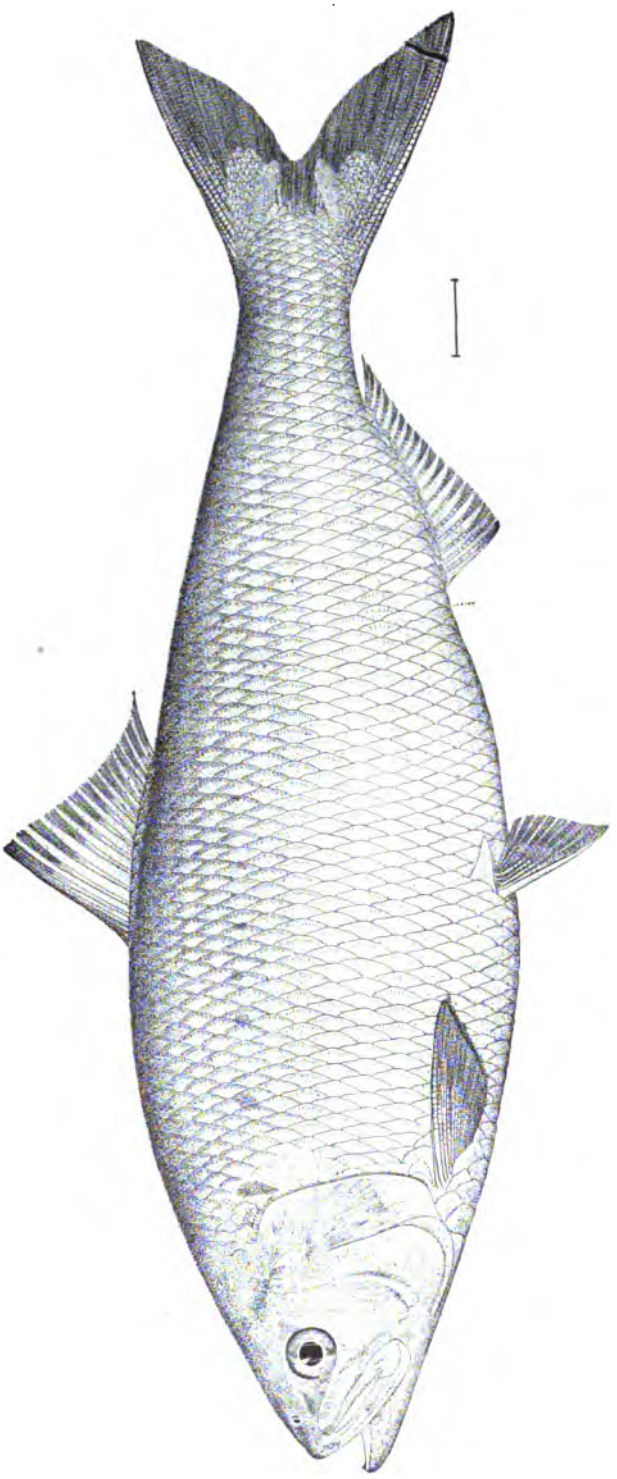
1903.



ALOSA SAPIDISSIMA. *Common Shad.*

THE SHAD.

DESCRIPTION OF THE SHAD.

The shad (*Alosa sapidissima*) is the largest, best-known, and most valuable member of the herring family in the United States. The body is deep and compressed, the depth varying with the sex and spawning condition, but averaging about one-third the body length. The head, contained about 4¼ times in the body length, is quite deep; the cheek is deeper than long. The jaws are about equal, the lower jaw fitting into a deep notch on the tip of the upper. Teeth are present in the young, but are not found on the jaws in the adult. The eye is contained 5⅚ to 6 times in the length of head. The gillrakers are long, slender, and numerous, there being from 93 to 120 on the first arch. The fins are small and weak, the dorsal containing 15 rays and the anal 21. The lower edge of the body is strongly serrated, the plate-like scales numbering 21 before the ventral fin and 16 behind it. The scales in the lateral line number 60. The body is dark-bluish or greenish above, silvery on the sides, and white beneath. There is a dark spot behind the gill-opening and sometimes a row of smaller spots along the side. The vertical fins often have black or dusky edges. The peritoneum is white. Supposed structural and color peculiarities in shad from different regions or basins have not been verified.

From the other clupeoids with which the shad is frequently associated in the rivers, it may be readily distinguished. In all of them the cheek is longer than deep. The hickory shad or hickory jack (*Pomolobus mediocris*) has a projecting lower jaw and a very straight profile. The river herrings or alewives are much smaller than the shad, have fewer and shorter gillrakers, and a larger eye (3½ in head). In the branch herring (*P. pseudoharengus*) the peritoneum is pale, while in the glut herring (*P. æstivalis*) it is black.

The female shad is larger than the male, the average difference in weight being more than a pound. The mature males taken in the fisheries of the Atlantic coast weigh from 1½ to 6 pounds, the average being about 6 pounds; the females usually weigh from 3 to 6 pounds, the average being 4¾ pounds. The general average for both sexes is between 3¾ and 4 pounds. In the early history of the fisheries, shad weighing 11, 12, and even 14 pounds were reported, but 9-pound shad are very rare on the Atlantic coast, and 10 pounds seems to be the maximum. Some seasons an unusual number of large shad (7 to 9 pounds) appear in certain streams. On the Pacific coast shad average a pound or more heavier than on the Atlantic, occasionally attaining a weight of 14 pounds; many have been reported weighing 9 to 12 pounds.

DISTRIBUTION AND ABUNDANCE.

The shad is distributed along the entire east coast of the United States, and northward and eastward to the Gulf of St. Lawrence. It has gradually spread from the Sacramento River, California, where it was introduced by the California Fish Commission, and is now taken from southern California (Los Angeles County) to southeast Alaska. In the early history of the country its abundance excited unbounded astonishment. Nearly every river on the Atlantic coast was invaded in the spring by immense schools, which, in their upward course, furnished an ample supply of good food. Notwithstanding greatly increased fishing operations and the curtailment of the spawning-grounds, the supply in recent years has not only been generally maintained, but owing to fish-cultural efforts has been largely augmented in certain streams, notably in the Kennebec, Hudson, Delaware, Susquehanna, Choptank, Potomac, Nanticoke, Rappahannock, York, James, Chowan, Roanoke, Neuse, and St. Johns rivers, and in Chesapeake Bay, Albemarle Sound, Croatan Sound, and Pamlico Sound, and the Sacramento and Columbia rivers.

SHAD IN THE OCEAN.

The shad passes most of its existence at sea, and little is known of its habits and movements when out of the rivers. The ocean areas to which it resorts are unknown, and what its salt-water food consists of has not been determined. In the Gulf of Maine it is known to associate in large numbers with mackerel and herring during the months of June, September, and October, being most numerous in June. It has been taken at North Truro, Massachusetts, in the fall, when the ocean temperature was from 43° to 49°. In the month of November, one year after another, it has been found on the west side of Sakonnet River, Rhode Island. In May and June it has been captured with mackerel a few miles northeast of Cape Cod Light. Some instances of capture indicate that under certain conditions the adults may remain in the fresh-water rivers a whole year. In November, 1890, 600 were taken in the Chesapeake Bay. It has been found in the Potomac in considerable abundance in August and September, and even during the last week in December. Its movements are largely controlled by the water temperature. It is believed that it seeks to occupy an area having a temperature of 60° or 70°, and that its migrations are determined by the shifting of this area.

SHAD IN THE RIVERS.

The annual migration of the shad from the ocean to the rivers is for the sole purpose of reproduction. It ascends to suitable spawning-grounds, which are invariably in fresh water, occupying several weeks in depositing and fertilizing its eggs in any given stream.

Its migrations from the sea are in quite a regular succession of time with relation to latitude. It first appears in the St. Johns River,

Florida, about November 15, the season of greatest abundance being February and March. In the Savannah River, Georgia, and the Edisto, South Carolina, the run begins early in January and ends the last of March. In the North Carolina rivers these stages of the migration are a little later. In the Potomac River advance individuals appear late in February, but the fish is most numerous in April. In the Delaware River the maximum run is about the 1st of May. It reaches the Hudson River the last of March, and is found in the Connecticut toward the end of April, is most abundant the last of May, and leaves the stream late in July. In the Kennebec and Androscoggin rivers, Maine, it is first taken in April and has left by the middle of July. In the St. John River, New Brunswick, it appears about the middle of May, and in the Miramichi River, New Brunswick, late in May.

The main body of shad ascends the rivers when the temperature of the water is from 56° to 66°, the numbers diminishing when the temperature is over 66°. Successive schools enter the Potomac from February to July, the males preceding the females. Of 61,000 shad comprising the first of the run received at Washington, D. C., from March 19 to 24, 1897, 90 per cent were males. Toward the close of the season males are extremely scarce.

The movement of the shad up the rivers is not constant, but in waves, causing a rise and fall in the catch. In some of the rivers the fishermen claim that a fairly well-defined run occurs late in the season, consisting of a somewhat different fish, known as "May shad."

The erection of impassable dams along the rivers and streams was probably the first thing to curtail the natural spawning-grounds of these fish and to seriously check their natural increase.

As shad enter the rivers only for the purpose of spawning, the fisheries are necessarily prosecuted during the spawning season, and often upon the favorite spawning-grounds. The increase of population necessitates a larger supply of fish and requires the use of more apparatus, and the number of shad that reach fresh water is therefore greatly curtailed by assiduous fishing with all kinds of contrivances in the estuaries and in the mouths and lower parts of rivers. Under these conditions of a restricted spawning area and increased netting shad would soon be exterminated without artificial propagation; or the fishery, at least, would greatly diminish and become unprofitable. Such a crisis was fast approaching in 1879, when the Fish Commission entered upon systematic work in shad propagation.

From their birth until their return to the rivers shad are preyed upon incessantly by other fish, so that the larger portion of the young do not survive their few months' sojourn in fresh water, and of those which leave the rivers each season probably not one in one hundred reaches maturity to deposit its eggs and contribute to the perpetuation of its species. In the rivers striped bass, white perch, black bass, and other predaceous fishes devour the young, and when they reach salt water, sharks, horse-mackerel, kingfish, etc., undoubtedly destroy many

adults. It has been observed by North Carolina porpoise fishermen that as the shad swim close along the shore the porpoises follow and feed on them till they pass into fresh water. In the rivers the adult shad is comparatively free from enemies.

To what extent the pollution of the waters has reduced the numbers of shad is not known, but acids, sawdust, garbage, oils, gas tar, and refuse from dye-works all tend to make the water of rivers unsuitable for them.

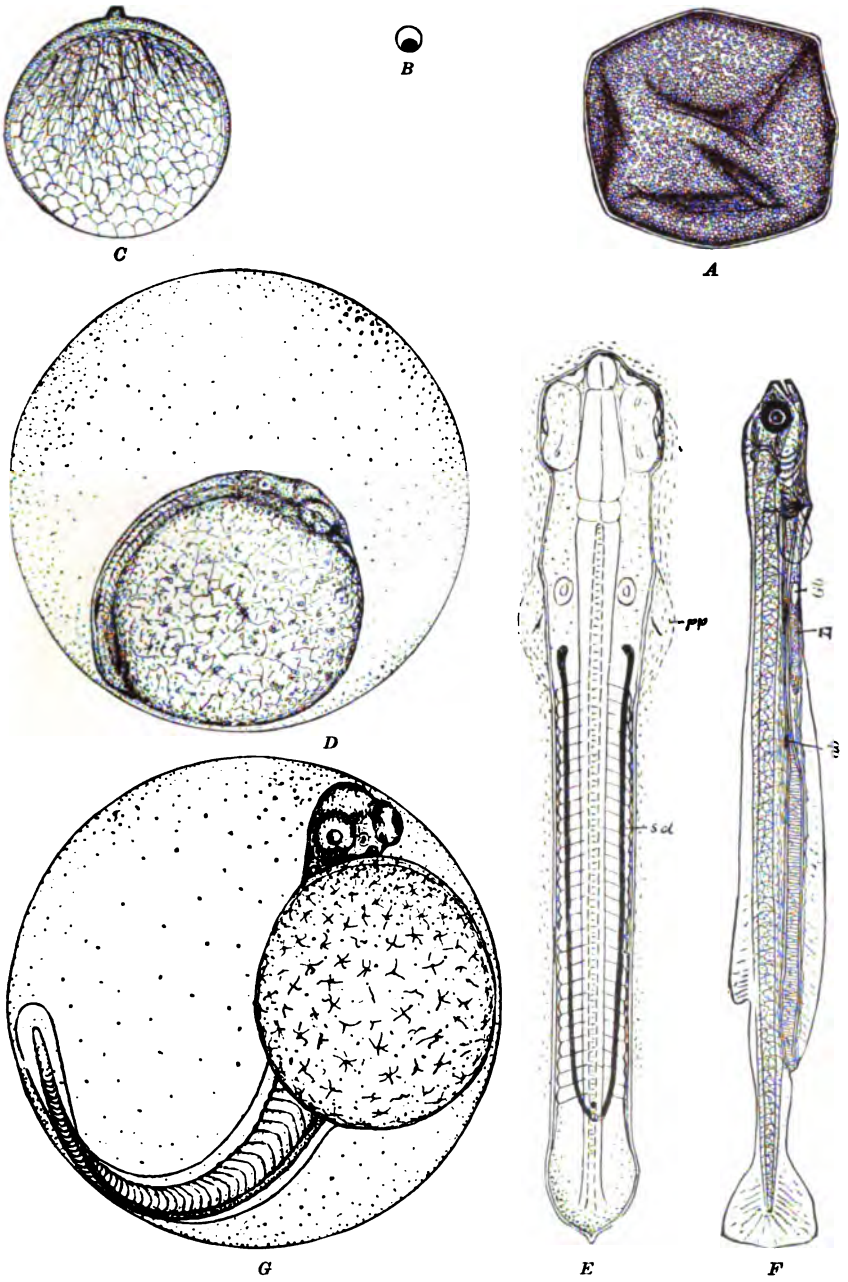
FOOD.

After entering the rivers, the shad takes but little, if any, food previous to spawning, but after casting its eggs it bites at flies or any small shining object, and has been known to take the artificial fly. The mouth of the adult is practically toothless, and its throat contains no functionally active teeth. The water which passes through the branchial filter—the gillrakers—is deprived of the small animals which are too large to pass through its meshes. It is a common remark with fishermen and others that food is rarely found in the stomach of the adult shad in fresh water, but examinations have shown that the shad does, in some instances, eat small crustacea, insects, etc. The only substance commonly found in its stomach in fresh water has the appearance of black mud. It is held by some that the shad swims with its mouth open and may unintentionally swallow the small organisms found in its stomach under such circumstances, but as far as observation of fish in aquaria and experiences of net fishermen go, the shad does not swim with its mouth open.

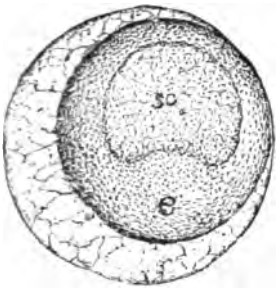
NATURAL SPAWNING.

Shad are liable to be ripe anywhere above brackish water, and under favorable temperature conditions spawn wherever they happen to be, but in some river basins they exhibit a well-defined choice of spawning-places, preferring localities below the mouths of creeks, where the warmer water of creeks mingles with the colder channel water. The shad lays its eggs during the highest daily average temperature, a condition realized about sunset, when the warmer shoal water commingles with the colder channel water, establishing a balance. The principal spawning occurs from 5 p. m. to 10 p. m. Observations on the Potomac River show that of the eggs from shad caught in a seine only 11 per cent were taken between midnight and noon, the percentage in the morning being 14 one year and 8 another.

The eggs in the ovaries remain in a compact mass until they ripen, at first occupying but a small space, but gradually increasing until they distend the whole abdomen, the average weight of the ovaries being about 13 ounces. Close examination at the approach of the spawning time will disclose large maturing eggs of rather uniform size and others smaller and of variable size. Whether the latter are the forming eggs for the next year, for two or three succeding years, or for the lifetime of the fish has not been determined, nor is it known whether shad spawn every year. The small and shrunken ovaries of a spent fish are still



A. Freshly extruded egg enlarged, showing its envelope much wrinkled and its surface covered with small round vesicles.
B. Shad egg, showing vitellus and distended egg-membrane, natural size.
C. Shows the gradual accumulation of germinal matter at one pole of egg, the polar prominence externally, and presence of plasmic processes extending down through the vitellus.
D. Embryo shad in its natural position in its spacious enveloping membrane. From a photograph.
E. Diagrammatic representation of an embryo to show course of segmental ducts *sd* and extension outward of pectoral plates *pp*, which are intimately concerned in the development of pectoral fins.
F. Side view of a young shad 13 days old, viewed as a transparent object. *ab*, rudimentary air-bladder; *L*, liver; *Gb*, gall-bladder.
G. An embryo in its envelope, on the third day of development, nearly ready to hatch.



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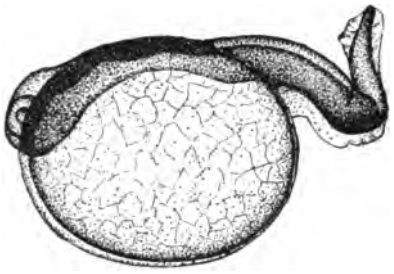

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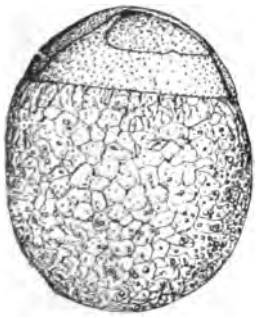

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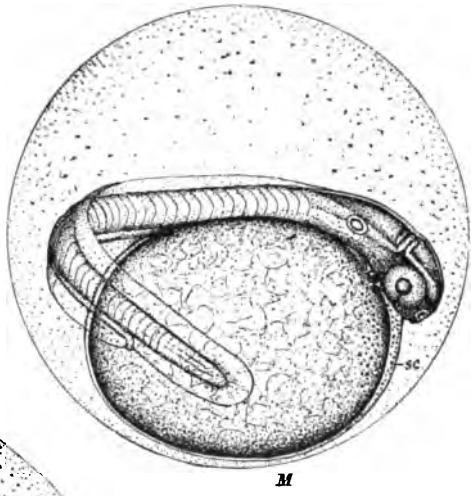

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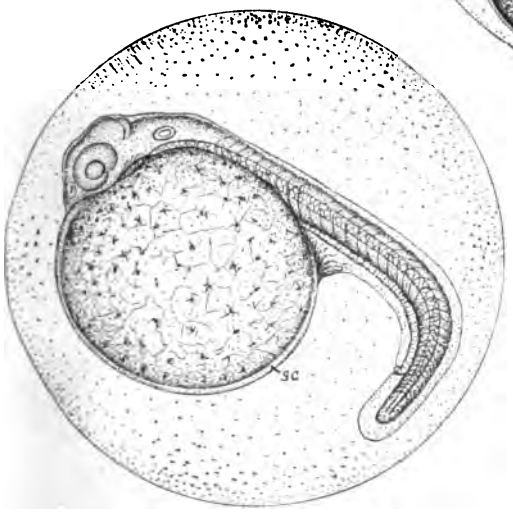

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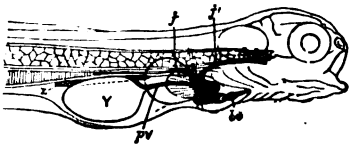

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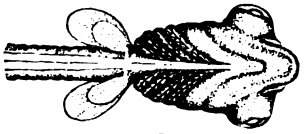


O

H and *I*. Two views of an egg after the blastoderm has spread considerably and the embryonic area *e* is well defined.

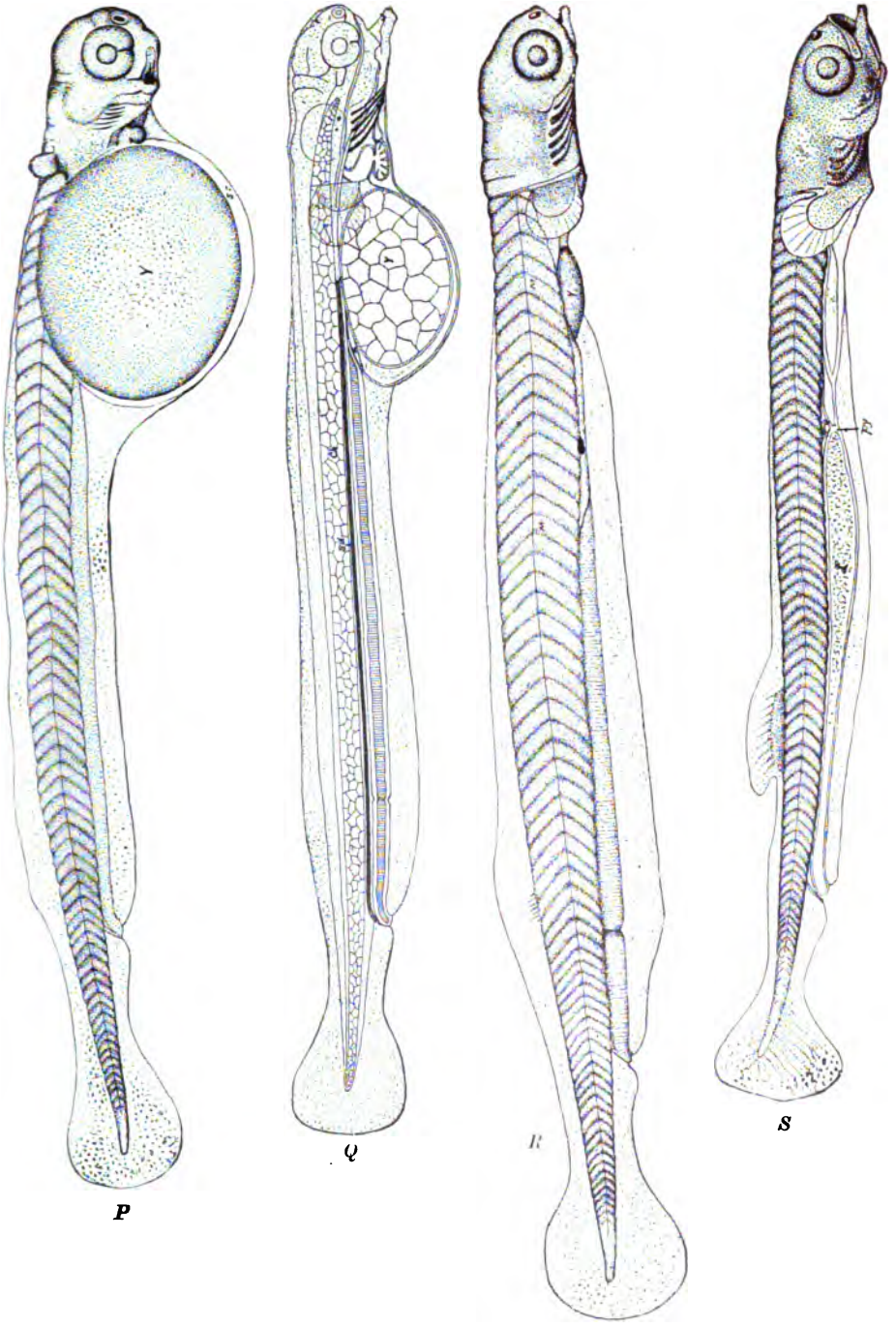
K. View of unhatched embryo, which developed in a temperature of 45° F., producing distortions of tail and notochord.

L. An egg-envelope with its contained embryo, forty-four hours after impregnation, viewed as a transparent object.

M. An egg-envelope with its contained embryo at the beginning of the third day of development. From a photograph.

N. Anterior portion of a young fish on fourth day. To show relations of liver *L* to yolk *Y*, over which the portal vessel *pv* passes forward to empty into the venous sinus, in common with the anterior and posterior jugulars *j'* and *j*, *ba* bulbus aortæ, *ve* ventricle.

O. View of fore part of a young fish 17 days old, from ventral side.



P. Young fish immediately after hatching, viewed as an opaque object and somewhat obliquely from one side, to display the relations of branchial and hyomandibular arcnes, and position of pectoral fin.
Q. Young fish third day after hatching, viewed as a transparent object to show extension of segmental duct forward; chorda *ch*.
R. Young fish 5 days after hatching, very much enlarged, and viewed as an opaque object. Only a slight remnant of the yolk-sac *Y* remains.
S. Young fish 17 days after hatching, viewed partly as an opaque and partly as a transparent object; *py* pylorus and rudimentary air-bladder above it; *I* intestine, filled with the remains of ingested food. The opercula are already so far developed as partly to conceal the gills.

found full of these eggs of different sizes. Shortly before spawning, transparent eggs of large size, contrasting strongly with the opaque golden hue of less mature ones, will be found scattered through the still compact ovarian mass, and, becoming more and more numerous, the ovaries disintegrate, the eggs fall apart, and extrusion begins, a liquid stream of eggs and mucus flowing from the oviduct on the slightest pressure of the abdomen.

Freshly deposited shad eggs are of a pale amber or pink color, and are transparent. They are about $\frac{1}{14}$ inch in diameter and somewhat flattened and irregularly rounded in form. The egg membrane is much wrinkled and lies in close contact with the contained vitellus. Immediately after fertilization the egg becomes spherical through the absorption of water and apparently gains very much in bulk, measuring about $\frac{1}{7}$ of an inch in diameter; but this gain is only the distended egg membrane, the vitellus or true germinal and nutritive portion not having increased. The vitellus is heavier than water, and a large space filled with fluid now exists between it and the membrane, the vitellus rolling about and changing its position as the position of the egg membrane is altered. No adhesive material is found on the outside of the membrane, though when first extruded the eggs are covered with a somewhat sticky ovarian mucus.

In a state of nature the shad deposits its eggs loosely in the rivers without building a nest, the two sexes running along together from the channel towards the shore, and the eggs and milt being ejected simultaneously. On quiet evenings, at the height of the season, spawning shad may be heard surging and plunging along the shores. By fishermen this is termed "washing."

Shad are very prolific, but much less so than many other food-fishes. The quantities of eggs taken by spawn-takers do not represent the actual fecundity, for many are cast in advance of stripping. The average number is not more than 30,000. Single fish have been known to yield 60,000, 80,000, 100,000, and 115,000 eggs; and on the Delaware River, in 1885, one yielded 156,000. Many eggs fail to be fertilized, and but a comparatively small percentage of those impregnated are hatched. After being extruded, the eggs sink to the bottom, where they remain until hatched, subject to the attacks of fish and other water animals. Eels are very destructive to shad spawn and often attack shad caught in gill nets, devouring the undeposited eggs and sometimes mutilating half the catch of a gill-net fisherman.

The development of fungus is one of the greatest dangers to shad eggs in a natural state, and another potent agency for their destruction is the mud brought down by heavy rains, burying and suffocating the eggs.

After spawning, shad are denominated "down-runners," "racers," and "spent fish." They are then very lean and hardly fit for food, but they begin to feed and have become fatter by the time they reach salt water in the summer or fall.

YOUNG SHAD.

In the Middle States the young fish remain in the rivers, feeding and growing, until the cool weather of fall comes on. They then begin to drop downstream, and by the last of November have passed out into the ocean or bays, and are lost sight of until they come back three or four years after, full-grown and ready to spawn. They leave the Potomac River when the water falls to about 40°. By that time they are about 3 inches long. For the last two or three years they have been observed in great abundance about Bryan Point, feeding and jumping out of the water about sunset. They keep within the open streak of water between the shores and the water-grass which covers the flats, in water 2 to 5 feet deep. After mild winters young shad have been found in the Potomac River in April, 30 miles above brackish water and 160 miles from the ocean, associated with young alewives and sturgeon. Some immature shad, apparently 2 years old, are caught each year in seines operated in the fresh water of the Potomac River, and undersized shad are frequently caught in the New England rivers, where the tidal waters are of little length.

COMMERCIAL VALUE.

The shad is one of the most palatable and popular of fishes. Its flesh is rich, but not oily, and the roe is considered a delicacy. It is the most valuable river fish of the Atlantic coast, and, next to the Pacific salmon, the most important species inhabiting the fresh waters of North America. In every Atlantic State from New Jersey to Florida, inclusive, it is the most valuable fish, and in New York it is second only to the bluefish. Among all the economic fishes of the United States only the salmon and cod exceed it in value, and, considering all branches of the fishing industry, only the whale fishery and the oyster fishery, besides the foregoing, are financially more important than the shad.

In 1896 the shad catch of the Atlantic seaboard numbered 13,145,395 fish, weighing 50,847,967 pounds, and worth to the fishermen $1,656,580. The value of the shad catch of the Pacific States in 1895 was $5,600, a sum representing 366,000 pounds.

EARLY ATTEMPTS AT SHAD-CULTURE.

The systematic development and extension of shad-culture were undertaken with the definite purpose of testing the value of artificial propagation in maintaining an important fishery which was being rapidly depleted. As early as 1848 shad eggs were artificially taken and fertilized, and in 1867 more extensive experiments were made on the Connecticut River, and later on the Potomac, with encouraging results. The attention of many States was thus attracted to the work, and in 1872 it was taken up by the general government. Prior to the experiments on the Connecticut, certain species of the salmon family had been principally dealt with in fish-culture, and different methods from those in use were necessary for shad-hatching, owing to the less specific gravity of shad ova and the much shorter period of time required for the development of the fish from the egg.

The "Seth Green box," a modification of the floating-box used for hatching trout and salmon eggs, was first tried with great success, but floating-boxes were subject to various accidents when used in tidal waters, and in rapid succession devices of various kinds were brought forward to supplant them. The most important were hatching-cones and the plunger-buckets, which, though imperfect, rendered larger operations possible. At this period the apparatus was arranged on flat-bottomed barges and towed from point to point along the coast from Albemarle Sound to the Susquehanna River, a slow and expensive method. The Chase whitefish jar worked with considerable efficiency, but required modifications, and finally the "universal" hatching jar now in use was adopted in 1882.

During the years of experimental work from 1872 to 1880, 97,471,700 shad fry were planted, beginning with 859,000 in 1872, while in 1880, 28,626,000 were distributed. Prior to 1880 deposits of a few hundred thousand each were made in as many different streams as possible, but the increased production of young fish made it possible to ship and plant the fry by the carload, and by 1884 shad-culture was established on a large scale, barge operations were abandoned, and the work conducted on shore. The basins of the Chesapeake Bay and Delaware River had meanwhile been selected by the United States Commission as the natural seat of operations, though the State commissions from Massachusetts to South Carolina were actively engaged on their own account. At present the States, except Connecticut, New York, Pennsylvania, and Maryland, have practically abandoned shad-hatching, leaving the work to the general government.

EGG-GROUNDS.

Every river on the Atlantic coast from Massachusetts southward has been examined by the agents of some State commission or the United States, or by both, in order to determine the natural spawning-grounds of the shad. On nearly every stream hatcheries have been operated at one time or another, but usually eggs were not obtained in sufficient numbers to justify continued operations, except in the Chesapeake and Delaware basins. However, it is not unlikely that after further investigation it will be found practicable to maintain hatcheries on rivers which have long since been abandoned. It is certain that work on the Albemarle Sound can be successfully conducted, and though operations on the Hudson River have not been on a large scale, better results may be there obtained in the future.

In certain river stretches, apparently favorable, no ripe fish are found; for example, in the Roanoke River for 15 miles above its mouth, where 10,000 to 15,000 shad are taken annually, mature eggs can not be found, though the fish spawn just below there, as they do many miles above at Weldon. In the Sutton Beach seine, the one in North Carolina waters which has afforded the most spawn, only about one spawning shad to each 100 is caught, and the annual catch of this seine is 30,000 to 75,000 per annum. In view of such facts, it is not remarkable that difficulty

has been experienced and time consumed in deciding on permanent locations for hatcheries.

The spawning period varies widely in different seasons; in some years shad are numerous and in spawning condition two or three weeks after the time when they have ordinarily disappeared. They deposit eggs at some point along the coast for six continuous months.

The following streams have been occupied by hatcheries, as some of them are now, and it will be observed that the approximate spawning periods, beginning early in the South, become gradually later toward the North.

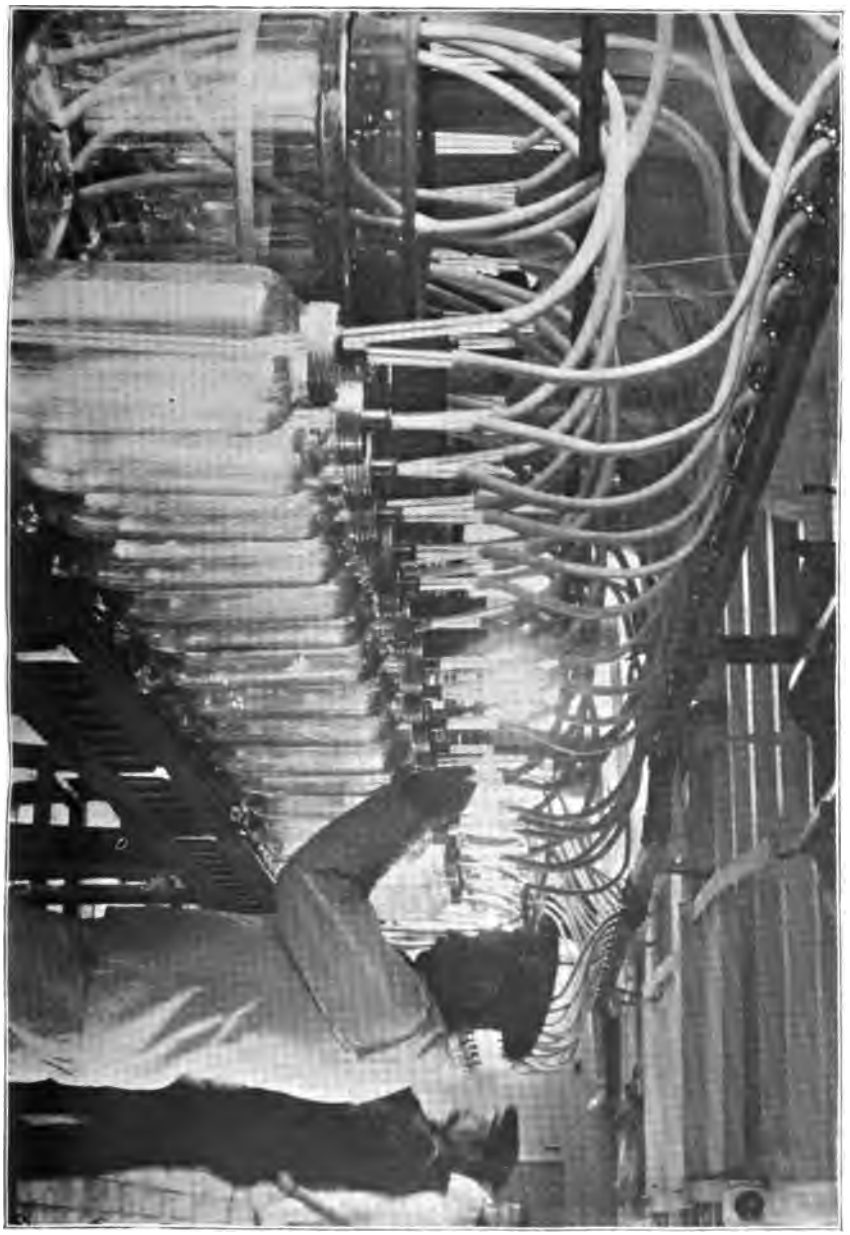
Waters.	Place.	Period.
Edisto River	Jacksonboro, S. C	Mar. 5-26.
Albemarle Sound	Avoca, N. C	Apr. 1-30.
Potomac River	Below Washington, D. C	Apr. 15 to June 10.
Susquehanna River	Below Havre de Grace, Md	Apr. 17 to June 15.
Delaware River	Gloucester, N. J	May 10 to June 20.
Hudson River	Below Albany, N. Y	May 15 to June 30.
Housatonic River	Birmingham, Conn	Do.
Connecticut River	Holyoke, Mass	June 15 to July 5.
Merrimac River	North Andover, Mass	June 1 to July 15.

The United States Fish Commission operates stations at Bryan Point, 12 miles below Washington on the Potomac, and at Battery Island at the mouth of the Susquehanna, while the steamer *Fish Hawk*, fitted up as a floating hatchery, is engaged during the shad season on the Delaware River. These two stations and the vessel can receive respectively 16,000,000, 40,000,000, and 12,000,000 eggs. On more than one occasion each has been taxed to its utmost capacity, but as the average hatching period is 8 days, and four of the special cars of the Commission are hatcheries in themselves and capable of taking 2,000,000 to 4,000,000 eggs aboard at a time, the hatcheries can be quickly relieved in case of emergency.

In 1897, 205,000,000 eggs were taken, from which 134,545,000 fry were hatched. In 1898, the total of shad fry hatched was 156,150,000, and in 1899 it was 210,493,000.

In 1900, a permanent hatchery located on an arm of Albemarle Sound, near Edenton, North Carolina, was operated for the first time. This station is adjacent to one of the most important shad fishing-grounds in the country, and is intended to replenish the waters of Albemarle, Croatan, Roanoke, and Pamlico sounds, and their tributaries—the Pasquotank, Chowan, Roanoke, Pamlico, Neuse, and various minor rivers. This region annually yields upward of 8,500,000 pounds of shad, valued at about $350,000, and contributes the principal part of the shad found in the northern and eastern markets in winter and early spring.

Potomac River.—The Potomac River, immediately adjacent to Fort Washington (12 miles below Washington, D. C.), is probably more productive of ripe shad than any other area of the same size. This was



MAIN DECK OF THE STEAMER FISH HAWK, EQUIPPED FOR HATCHING SHAD.

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discovered as early as 1880, and a station was soon developed there with steam pumps, tanks, and hatching vessels. The seine operated at this point between 1887 and 1891 furnished 23 per cent of all eggs from the river.

The following table, taken from the records of the station, shows the value of the spawning-grounds:

Years.	Number of eggs taken.	Years.	Number of eggs taken.
1880	20,749,000	1891	32,980,000
1881	43,200,000	1892	13,446,000
1882	21,800,000	1893	9,423,000
1883	24,274,000	1894	32,393,000
1884	19,000,000	1895	66,065,000
1885	22,576,000	1896	64,788,000
1886	36,362,000	1897	39,707,000
1887	59,435,000	1898	68,724,000
1888	81,177,000	1899	49,283,000
1889	58,233,000	1900	67,904,000
1890	35,202,000		

In 1889 immense collections of eggs were made on certain days—8,368,000 on May 6 and 6,311,000 on May 7, and during seven days there was an average of over 5,000,000 per day. This was before and just after a freshet.

To increase the supply of eggs, seine fishing has been attempted by the Commission on both the Susquehanna and Potomac, but the efforts were only partially successful and were finally abandoned. The extension of egg-taking by seines can not be relied upon, especially as this method of fishing has been declining for many years, owing to its greater expense, and a corresponding growth has taken place in the gill-net fishery. It is often difficult to obtain the ripe eggs when the shad are taken in a seine on account of the great numbers of alewives taken at the same time.

The following comparative table shows the shad-egg production from a Potomac River seine, together with the proportion of males, females, and spawning fish, and the number of eggs per fish:

Year.	Total number of eggs obtained.	Total ripe fish.	Total shad caught.	Per cent of males.	Per cent of females.	Average number of eggs per fish spawned.	Per cent ripe.
1887	20,956,000	652	10,348	71.4	28.6	32,100	6.3
1888	22,657,000	688	11,212	69.2	30.8	32,900	6.1
1889	17,738,000	612	6,217	52.3	47.7	28,980	9.8
1890	10,262,000	468	4,606	54.3	45.7	21,900	10.1
1891	5,276,000	228	3,138	57.1	42.9	23,140	7.2

Had all other fisheries furnished an equal percentage of eggs, the annual Potomac collections would have reached about 300,000,000. But while the Fort Washington seine, with a catch of 10,000 shad, gave 20,000,000 eggs, and another, capturing 18,000, gave 17,000,000, a third catching 60,000 shad, gave only 1,000,000.

Eggs taken by gill fishermen are usually superior to those from seines, and the gillers attach enough value to the market for eggs to save almost all within reach. At the commencement of the season many of them secure spawning-pans, which they keep in their boats, taking and fertilizing the eggs themselves, and when accidentally overlooked by the regular spawn-takers they sometimes row several miles to bring in pans of eggs. In 1896 a giller who laid out his net with the special object of securing spawning shad, caught 3,300 fish and sold over 6,000,000 eggs to the Commission. About 1,100 of his fish were roe shad; of the total, about 6 per cent were ripe; of the 1,100 roe, about 20 per cent were ripe.

The average catch of shad by the gillers who supply eggs is 1,600 to 1,800 per season; but they do not all operate specially for the capture of spawning fish, though this work is profitable and gillers are fast turning attention to it. The Fort Washington gilling boats furnish on an average about 1,000,000 eggs each a season, those at White House 400,000, Sandy Bar 350,000, Greenway 300,000, and Craney Island 150,000, the average being about 500,000 per boat.

Susquehanna River.—The shoal water in the neighborhood of Battery Station is an extensive and valuable spawning-ground. The station is conveniently situated on an island and the possibilities in egg-collecting appear to be almost unlimited. Hundreds of gill fishermen are engaged and large seines are operated within easy distance. In 1886 the station was overrun with eggs; 170 universal hatching-jars and 58 cones would not contain them, large numbers being held in cylinders, buckets, and pans. In 1888 over 105,000,000 were taken, and in 1889 7,600,000 were obtained in one night. Both egg-collecting and hatching are carried on, and the establishment is complete in itself. There is no transfer of the eggs except for occasional car shipments, and the fry are carried to Havre de Grace in 10-gallon cans for railroad transfer to the places of deposit.

Delaware River.—The steamer *Fish Hawk* has been employed in shad-hatching on this river nearly every season since 1887, the egg-collecting and other labor being performed by the crew. An interesting feature of the work is the large yield of eggs per fish. Eggs from this river have been saved regularly since 1887 from seines, but the available product among the gill fishermen has never been fully ascertained.

The eggs collected by the *Fish Hawk* numbered 51,983,000 in 1899.

The methods pursued at the different shad hatcheries are very similar. The following description applies particularly to the work on the Potomac River at Bryan Point.

BATTERY STATION HATCHERY, HAVRE DE GRACE, MARYLAND.

EGG-COLLECTING.

Collecting eggs is the work of experienced watermen, who must be prepared to endure all kinds of weather in open boats. The boats are towed out to the fishing-grounds by steam-launches, where the spawn-takers visit the nets of the market fishermen, obtaining from them the spawning fish. After eggs have been obtained a ticket is dropped into each panful, with the date and the name of the fisherman, for entry on the books of the station. The price for eggs is always above the market price of the shad, and payment is made at the end of the season on the basis of 28,000 to the liquid quart, the price being $10 to $20 per 1,000,000. On the Potomac 40 to 50 spawn-takers are employed at the station, besides 12 or 15 men who are engaged as hatching attendants, machinists, firemen, and cooks.

The spawn-taker uses a 16-foot flat-bottomed bateau and is provided with a lantern, six small and four large spawn pans, and a dipper of suitable size. The pans are made of tin and are of two sizes, 11-inch and 18-inch diameters, the latter with handles. The smaller are for receiving eggs on delivery from the fish, and the larger for carrying them. The pans are thoroughly washed each night after use and not allowed to become rusty or indented. The dippers are round-bottomed, hold nearly a quart, and have handles with open ends, with 5 inches of the free end wrapped with seine twine. To obtain eggs from a seine, double the above number of spawn vessels may be required.

Spawn-taking tubs of indurated wood fiber have been introduced in Potomac River operations and found superior to tin, being without hoops or joints, non-corrosive, and non-conductors of heat. They have wood covers which fit inside the rims, and the tops fit tightly by means of a soft rubber joint: 4 inches of the central part of the cover is cut away to admit air.

As the shad manipulated are sold and consumed in a fresh state, fishermen waste no time in transferring them to market boats, which are in waiting, and rapidity of execution is therefore required on the part of the spawn-taker, who must be alert and exact in his methods.

In gill-net fishing there is usually ample time to assort the fish, which are taken into the boat one at a time, except when sudden squalls or exceptional captures force the premature hauling in of the net with the fish wound up in the meshes. Unskilled spawn-takers are liable to the mistake of stripping eggs without having the necessary milt to impregnate them, for several spawners may be taken over a period of ten or twenty minutes without the capture of a male fish. In such cases (of great frequency late in the season) the female fish must be placed conveniently, backs down, to prevent the eggs from running out, and the males may have to be obtained from other boats. When ripe shad are taken in seines, two or three large baskets should be in readiness to receive them.

Sometimes the number of ripe fish will be sufficient to occupy all the attention that can be devoted to them; at other times the run of fish

is greatly reduced by local conditions. Even when other conditions are satisfactory, if neither high nor low water occurs about sunset but few ripe fish are caught. The large seines land toward the last of the ebb tide, and gill-net fishermen can do nothing except on the change of the tide—on slack water. The fish spawn at a certain time of day, and when taken at other hours are not in spawning condition. Thunderstorms sometimes occur for days in succession about sunset, the very hour when most disastrous.

A scarcity of male fish toward the end of the season often cuts short operations when eggs are plentiful. Unsuccessful attempts have been made to capture the males at such times by using gill nets with meshes smaller than those in the nets of market fishermen. Attempts have been made to pen the adults, but without success, as the fish become diseased and their eggs spoil within them. In gill nets the adult is entangled in the mesh and can not escape by struggling, and it therefore remains comparatively quiet.

The quality of shad eggs is generally impaired where the fish are held for an hour or more in trap nets or seines. The eggs from fish taken in large seines are usually of bad quality, but those from short seines, which are landed quickly after the fish have been surrounded, are usually good; and those from trap nets, in which the fish have been held for some hours, are valueless. Eggs are rarely susceptible to fertilization longer than 20 minutes after the fish are taken from the water, though there are exceptions to this rule. On May 23, 1895, Potomac shad were stripped which had been out of the water about 1¼ hours; they were kept separate, and at the end of 48 hours produced 100,000 eggs, which yielded 98,000 fry.

The shad dies very quickly after capture and is immediately responsive to electrical storms, the catch of seines and nets of all kinds falling off promptly when a thunderstorm develops. Even in seines already laid out in the water, with lead line on the bottom, there is an appreciable decrease in such event. On the Delaware River, May 29, 1887, nearly 50 per cent of the shad eggs on board the steamer *Fish Hawk* perished during an electrical storm which continued from 6 p. m. to midnight. There were 4,481,000 eggs with embryos well formed, and without perceptible change in water temperature 1,918,000 were killed, many turning white by 8 p. m.

Heavy freshets cause an abrupt suspension of fishing, but the effect of a single freshet is usually temporary. The shad which have gone above are backed down before the muddy water, but reappear upon its outward passage. An occurrence of this kind will effect a great increase in egg receipts if the water temperature before muddy water comes is suitable. The shad that were scattered above being thrown back in a body, reascend in a body.

A season of clear water is undesirable both for fishermen and hatching work, as the fish see the nets and avoid them, gill nets being put out only on the night tide and half the fishing being thus lost. The water

should be discolored enough to prevent the fish from seeing the nets, but not thick, say from 10 to 20.* An occasional freshet reduces the temperature and prolongs the season; however, with an equal number of fish in the rivers, clear water is probably more advantageous for natural increase, as a large proportion of naturally deposited eggs must perish from suffocation under the mud in seasons of freshet.

THE WEATHER AND SPAWN.

The development of eggs within the ovaries is hastened by heat and retarded by cold. In a warm season fish ready to spawn are more numerous early in the season than in a cold one, and the period for obtaining them is apt to close earlier. The eggs, not only after they are deposited and impregnated, but before they leave the body of the fish, are affected by the temperature of the water, often being "blighted" or "rotten ripe." This phenomenon was observed as far back as 1873. It occurs on the water reaching 80° to 81°, or with a rapid rise. On the other hand, a sudden fall in temperature has been observed to arrest natural spawning, produce blighted eggs, and to destroy those in the hatching-vessels. Continued low temperature is also disastrous to fishing.

An abnormally inferior quality of the Potomac River eggs was noticed during the full period of operations in 1896. The bulk of the run of shad made their appearance on a rapidly ascending temperature, and the eggs were injured within the parent fish, more than half perishing before conversion into fry. The rise in temperature was greater than had been recorded in the eleven years preceding. The run of shad increased proportionately, the catch at one seine increasing from 100 to 800 in 24 hours. A snowstorm on April 7—morning air temperature 35° F. and mean air temperature 46°—was followed by heavy frost on April 9, the morning air temperature on the last-named date being 34°. The river water on April 10 was 46°, rising to 48° on April 12 and to 71° in the afternoon of April 21, thus gaining 25° in 10 days. After April 21 the catch of shad fell off to such an extent that fishing was no longer profitable.

The water of the Potomac early in March is usually of a temperature of 36° to 40°, rising to 52° to 58° about the middle of April, when the spawning period begins, and at the end of May, the close of the period, it averages from 65° to 70°.

STRIPPING AND FERTILIZING THE EGGS.

In stripping the eggs the shad is lifted with the right hand and caught above the tail with the left. All slime and loose scales are removed by going over the fish two or three times in quick succession with the right hand. The head is carried to the left side under the

*The condition that permits the discernment of objects at a distance of 10 to 20 inches beneath the water surface, the method of registration employed by the Washington (D. C.) aqueduct office.

arm and there retained by the arm, the tail being bent slightly upward with the left hand. When the fish is properly adjusted its head is nearly concealed. The fish is held firmly over a moist pan, and with a moderate downward pressure of the right hand the eggs will flow freely if mature. The strokes are continued until there are signs of blood, which usually accompany the last eggs. The fingers should not touch the gills of the fish, as laceration of these organs causes a flow of blood injurious to the eggs. Two fish may be stripped into each pan.

As soon as the spawn is all obtained, the shad is discarded, it being impossible to preserve the life of such a delicate fish, even with the utmost care. But though it has slight tenacity of life when taken from the water, the shad is a very muscular fish, and if not firmly held it will flounder and splash in the pan of eggs and probably throw a large proportion out and damage some of those that remain.

The first half teaspoonful of eggs should be pressed out into the palm of the left hand and inspected. Skilled operatives can usually discern ripeness by general outward appearance. A slow and yet almost positive test consists in running some of the eggs into water, when, if dead, they will have the appearance of boiled rice. But bad eggs are sometimes beyond the detection of the most skilled fish-culturists. If the eggs are white, opaque, or of milky appearance, the fish is put aside. Immature eggs are white, small, and adhering in clots; or they may be transparent and yet unyielding to pressure. The former are valueless, while the latter can sometimes be utilized by putting the fish aside to soften. Both ripe and green eggs sometimes occur in the same fish, but only expert operatives can hope to take the one and leave the other. If eggs are mature, but little pressure is necessary to start them, and if not, they are only injured by squeezing, and will either not flow at all, or will come away with difficulty in clotted masses and generally with a little blood. After the spawn is taken away, the fish has a soft and flaccid appearance about the abdomen, which after natural spawning becomes contracted and drawn up, tapering slenderly toward the tail.

Eggs of the best grade may be impaired by intermixture of overripe or green ones, lumps of milt, tissues of the sperm sac, or fish scales. The overripe and unfertilized ones can be discarded, and a tiny net, an inch square, or a straw or twig, may be used in removing foreign substances. The spawn-taker should clean the eggs before delivering them at the hatchery, and no subsequent care can compensate for his neglect. Experienced men rarely bring in bad eggs, unless as a result of variable and unfavorable weather conditions.

To obtain the milt the spawn-taker catches the fish by the back, taking hold of the under side with the right hand. Without relaxing pressure at any point the milt is forced out with the thumb and forefinger. Good milt is so thin that it flows in a steady stream, and from some fish it can be ejected widely over the surface of the eggs, but in

fish which have been dead some minutes the milt is lumpy and flows only in drops. A teaspoonful will fertilize 40,000 to 75,000. After the milt has been applied, from half a pint to a pint of water from the river is added and the pan given a slow rotary motion, continued till the milt is thoroughly mixed, when a milky appearance is imparted to the water. When the river water is turbid, clear water must be obtained before work is commenced.

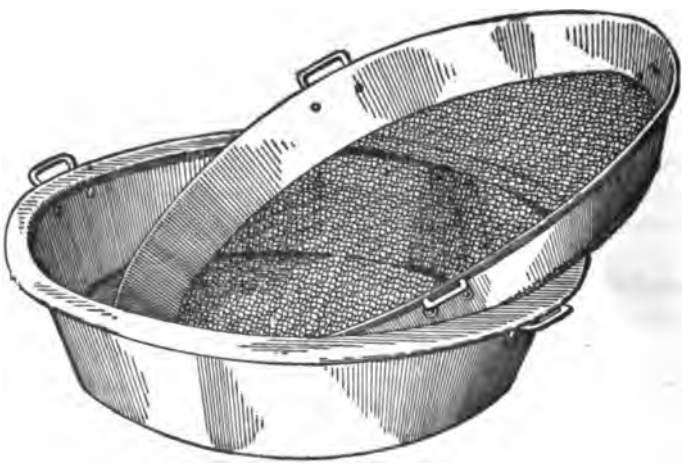
In gill-net boats eggs thus treated will expand without further immediate attention, for there is sufficient motion from the boat to prevent clotting; shad eggs do not "cement" when the milt is applied to them, as in the case with salmon and trout eggs; but they adhere, and if left perfectly quiet, as on shore, a large proportion will be lifeless. Those comprising the lower strata may either lack sufficient expansive power to absorb water under weight of the others, or in the suction of each separate egg, in the natural tendency to absorb water, they may have a cupping effect upon one another, thus preventing water contact. Whatever the cause, they stick together in one mass, and only those of the upper layers receive sufficient water; the others remain undersized and die. Large quantities of eggs must be separated, either by agitating the water already in the pan or by the addition of more.

In one minute after thorough mixing the milt can be washed off with safety, but usually several pans are to be looked after, when the milt may be allowed to remain 5, 10, or even 15 minutes. After the last pan of eggs has been fertilized, they are rinsed, beginning with those first taken, by pouring in a quart of water, placing the edge of the dipper so that the stream is directed between the eggs and the sides of the pan, as the eggs may be injured if the water is poured directly upon them. Then the pan is oscillated, the water being drained over the edge slowly, and, the operation being repeated, the third quart of water is left upon the eggs. The eggs must be well stirred with the inflowing water.

There need be no fear of applying too much milt. The amount obtained from one fish may be ample for the eggs from two, but it is always better to employ two males. Eggs may look promising for two or three hours, yet never expand to full size or produce fish. They lie at the bottom, and underneath any good ones which may be in the pan; they stick to the fingers, while the good ones will not, nor can they be successfully removed from hatching-jars until after several days' decomposition. By using two pans, good eggs may be separated from bad by pouring, but the process is slow and there is usually no time in the hatcheries for such operations.

Good eggs are very transparent and so soft and light that they are not apparent to the touch when the fingers are moved among them. When the temperature is about 70°, no change is observed for about 12 or 13 minutes after the milt is added, but about this time a careful movement of the fingers in the pan discloses their presence, and in a

little more than 20 minutes from the time the milt is applied they feel like shot against the fingers, and to an experienced eye are observed to increase slightly in size; when a day old, they will not break if dropped to the floor. In transferring to other vessels, the rim of the smaller pan should be gently immersed beneath the water surface in the larger one, and the pouring take place gradually. To prevent splashing, in boats, a small pan should be put on the water surface of the larger pan. Sudden jars must be avoided, all foreign substances excluded, and the pans be free from grease and salt. After the application of milt they expand to full size in 20 to 60 minutes, depending partly on temperature, and at this stage they may be doubled up in the larger pans, the question of safety in moving them being determined by their hardness.



Pans used in cleaning eggs.

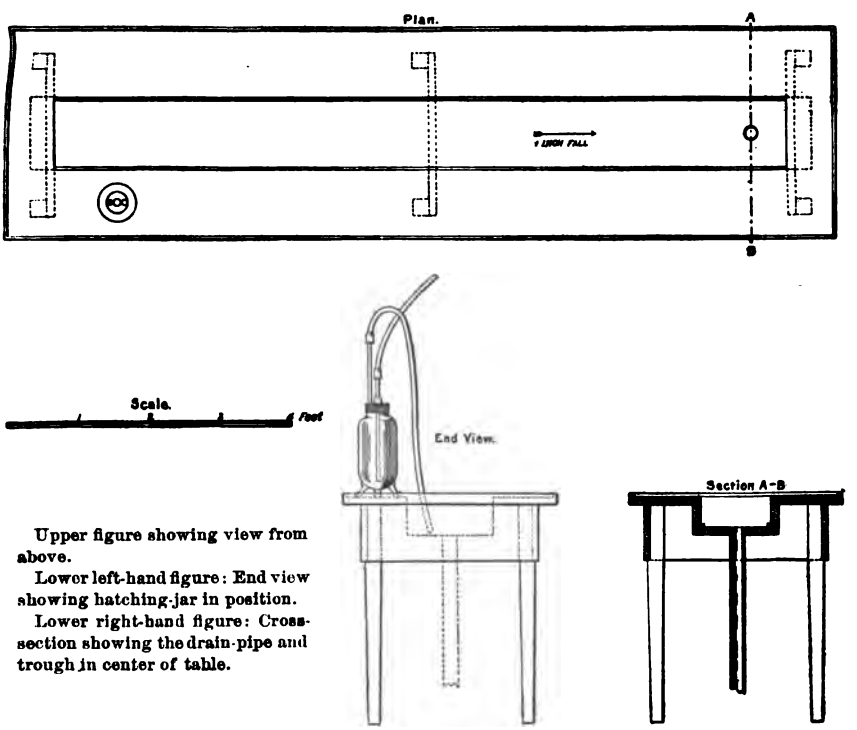
When eggs are received at the station, in order to thoroughly remove all impurities they are passed through netting, and for this purpose, two 18-inch flared tin pans with handles, one pan fitting within the other, are employed; 2 inches of the bottom part of the inner pan are evenly cut off and replaced with quarter-inch (bar) twine netting. The lower pan is filled with water to a point just above the netting, and then several quarts of eggs are gently poured in, when they drop through the meshes, leaving the fish scales, etc., behind. Thus they are also given a change of water, which should be clean and fresh and of about the same temperature as that in the hatchery and river.

If the eggs have absorbed sufficient water in the spawn-pan, they swell and adhere to each other, forming a compact mass, and are ready to be transferred to the hatching-jars, but if they are not sufficiently expanded or "water-hardened," they must remain in the pans, from 30 to 60 minutes being required for their full expansion.

HATCHERIES AND EQUIPMENT.

The building for a shad-hatchery may be of a temporary character, as it is used only about two months each year, but ample light, space, ventilation, and arrangements for moderate heating are necessary. The steam boiler and pumps should be in a separate structure.

In exceptional cases, as at Central Station, in Washington, river water from city pipes can be utilized. If the water supply is taken directly from the river the suction should be put below low-water mark, and the end provided with a strainer and kept off the bottom to avoid sediment. The water should be supplied from an open tank, not by a force-pump, but if it is taken from municipal pipes a regulator may be employed. A fall of 16 feet is desirable, or 8 pounds pressure per square inch at the top of the hatching-jars. The amount required is 2 quarts per minute to each jar.



Upper figure showing view from above.

Lower left-hand figure: End view showing hatching-jar in position.

Lower right-hand figure: Cross-section showing the drain-pipe and trough in center of table.

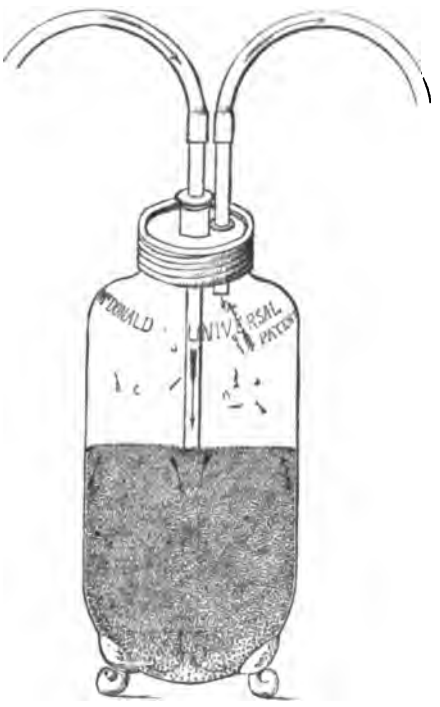
Shad-hatching table.

The jars are arranged on tables, as shown in the cut. From a large iron pipe, branch piping of 1½ to 2 inches diameter is run over each table, where ¼-inch brass pet-cocks are inserted 6 inches apart. The jars are connected with the supply-pipes by half-inch rubber tubing. Tight drains are required to carry away the waste water. Collector-tanks for fry are rectangular and may be of glass or wood, the former possibly preferred.

The overflow from the collectors is guarded by a wire-gauze or cheese-cloth strainer. A safe and interchangeable device consists of a stout wire frame, over which a cheese-cloth bag is drawn and tied. A $\frac{3}{4}$-inch rubber hose is attached to the opening in the frame. The strainer is put inside among the fry, and the outflow in an overflow cup. The overflow cup is set at the proper height to control the water level in the collector-tank. Long-handled nets of $\frac{3}{16}$-inch mesh are required to remove egg lumps or other matter from the jars.

THE AUTOMATIC HATCHING-JAR.

The United States Fish Commission, in the development of its work, had presented to it the necessity of dealing with the eggs of the whitefish and the shad upon a scale unprecedented in the history of fish-culture. Millions were to be handled instead of thousands, and the removal of dead eggs by hand picking was no longer to be considered. After successive experiments the McDonald automatic hatching-jar was devised, and it is now generally employed.



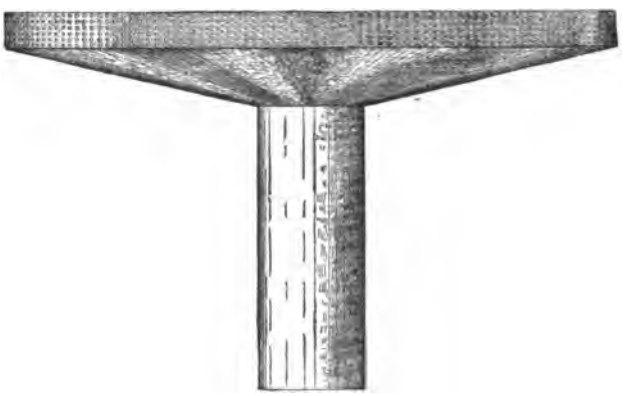
Automatic shad-hatching jar.

The most meritorious feature of this apparatus is that it prevents the development of the saprolegnious fungus, which caused so great a mortality in some other forms of hatching contrivances in which all the ova were not in continual movement. The very gradual, gentle, and continual rolling movement of the ova upon each other in the jar apparently prevents the spores of the fungus from adhering. The cleanliness of the apparatus is also advantageous, and as the material of which it is made is glass, the progress of development can be watched satisfactorily from the outside of the jar with a hand glass or pocket lens of moderate power.

The jar is a cylindrical glass vessel, of about 7 quarts' capacity, with hemispherical bottom, supported upon three glass legs. The top is made with threads to receive a screw cap. It is closed by a metallic disk perforated with two holes five-eighths inch in diameter—one in the center admits the glass tube that introduces the water into the jar, the other, equally distant from the central hole and the edge of

the metal plate, admits the glass tube which carries off the waste water. The central tube is connected by half-inch rubber tubing with the pet-cock, which regulates the supply of water. A groove in the inner surface of the metallic plate carries a rubber collar, and when the plate is in place the tightening of the metallic screw-cap seals the opening hermetically. Both the inlet and outlet tubes pass through stuffing-boxes provided with gum-washers and binding-screws. The central or feed tube is provided with stuffing-boxes, one on the top of the disk and one on the bottom, the better to hold it to a true center. The outlet tube is provided with only one stuffing-box, and the binding-ring is beveled.

In preparing the jar for work the side tube is fitted first. The glass tube should be wet, the gum-washer slipped on the tube about an inch from the end and introduced into the opening. Holding the tube perpendicularly to the face of the plate, press fairly on the tube, and the washer, rolling on itself, will fall into the seat provided for it. Screw on the binding-ring, and test by seeing that the tube slides freely back and forth in the stuffing-box; if not, it should be refitted with a heavier or lighter washer, as may be required. Glass tubes can not be procured of absolute uniformity in size. Water is the only lubricant that should be used about the jar fittings.



Egg Funnel.

The jar, after being washed clean, is filled with fresh water. A shallow tin funnel with a perforated rim is inserted, so that the water will stand as high in the funnel-throat as possible, and the eggs are poured in by dipperfuls, or when taken from transportation trays are washed in by a jet of water. Care is used to have the eggs fall but a short distance, and no fish scales or other foreign matter should enter the jar with them, as the presence of anything but water and eggs renders a proper motion of the mass impossible, and usually results in the loss of a large proportion of the eggs. The requisite number of eggs, 80,000 to 100,000, being in the jar, it is put in position and closed, care being taken that both the inlet and outlet tubes slide freely in their stuffing-boxes. If the tubes become gummed, let water trickle down around the binding-screws. To close the jar, turn on the water, place the feed-tube in the jar, turning off the water immediately after the feed-tube has passed beneath the surface of the water in the jar,

thus expelling all the air from the feed-tube; otherwise it would rise in bubbles, throwing a portion of the eggs out through the outlet-tube.

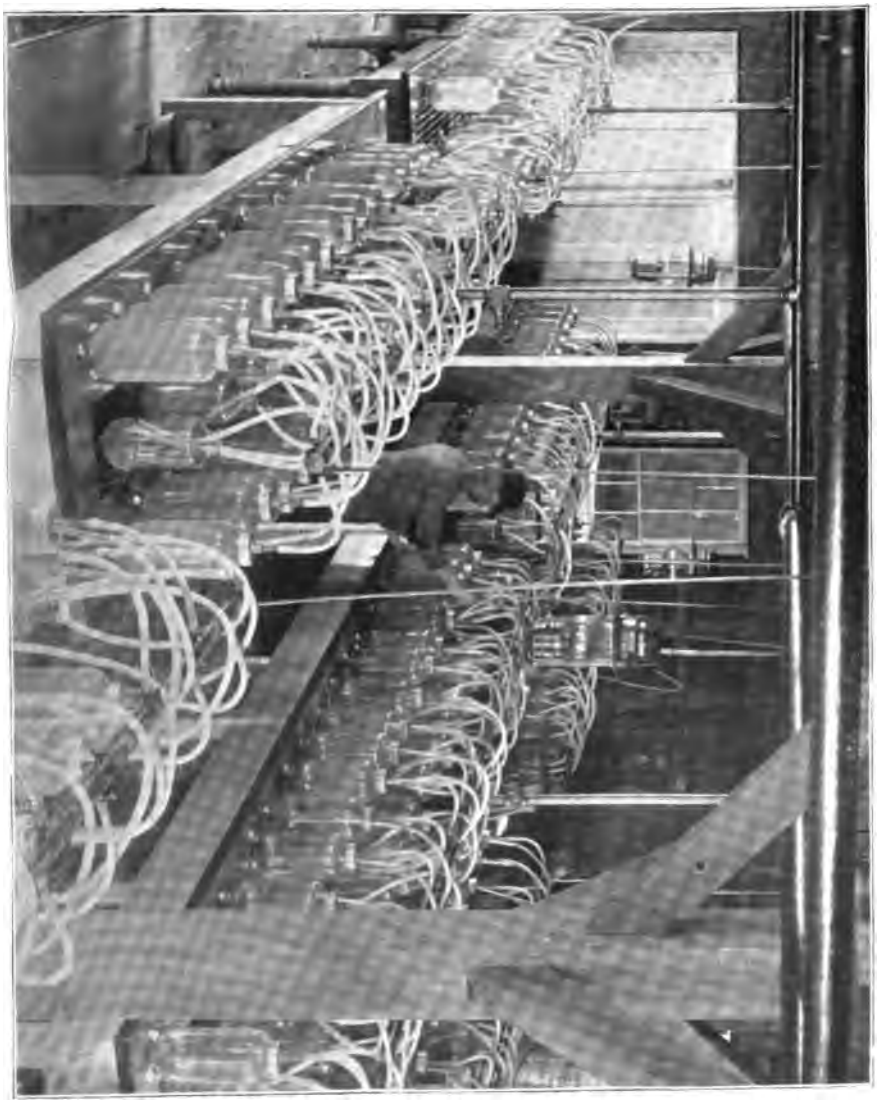
With a proper quantity of semi-buoyant eggs in the jar and the water turned on and regulated, the movement of the current establishes a regular boiling motion in the mass of eggs, which brings each in succession to the surface. This motion may be regulated without altering the quantity of water. By loosening the upper binding-screw of the central stuffing-box, and pushing the feed-tube down until it almost comes in contact with the bottom of the jar, the motion of the eggs is increased. If the jar is working properly, the dead eggs when brought to the surface remain on top, forming a distinct layer, and by pushing down the outlet tube a suitable distance they are lifted up by the escaping current and taken out.

When the water is turned on for the first time the jar should be watched closely until a regular motion has been established. When eggs have stood 15 or 20 minutes in the jar before the water is turned on they do not readily yield to the boiling motion, but tend to rise in a solid mass to the top of the jar. By quickly starting and stopping the current the mass is readily disintegrated. The degree or intensity of motion of the eggs varies not only with their age and condition, but also with the condition of the water. If the water is muddy, the motion should be rapid enough to prevent mud settling either on the eggs or in the bottom of the jar. Ordinarily the best motion is that which readily brings the dead eggs to the surface. After the hatching has progressed far enough to dispose of a portion of the eggs there is less resistance to the current, and it should be reduced by shutting off part of the supply or by slightly lifting the central tube. If the motion is not reduced from time to time as the hatching progresses, shells will be carried over into the receiving-tank with the fish and, being very light, will be drawn against the outlet screen, causing an overflow. The motion should be so gentle at the time of the greatest hatching as barely to induce the fish to swim out of the jar and leave their cast-off shells behind.

Very healthy eggs, exposed to bright direct sunshine, hatch so rapidly that the combined effort of the swarming mass of young fish will establish sufficient current to draw some shells over into the receiving-tank. This may be modified by placing a screen between the jar and the light. The shells under normal conditions remain and form a cloud-like layer above the mass of working eggs. As they accumulate they should be removed by shoving down the outlet-tube until they are drawn up with the escaping water. A good plan is to draw several jars in succession into a large pan, whence any fish coming over with the shells may be ladled into the receiving-tank.

A remnant of eggs may be long in hatching, and they should be poured into a large, clean, bright pan and exposed to bright sunlight, when they will hatch in five or ten minutes.

If the connection of the jar must be broken, it is essential that the rubber feed-tube does not drop down and siphon the eggs from the jar.



INTERIOR OF HATCHERY AT BATTERY STATION, EQUIPPED WITH HATCHING-JARS

In reconnecting, the air may be expelled with the metal top screwed down in position. To effect this, draw both glass tubes up to the top of the jar and turn on a full head of water, when the air will be forced out in bubbles above the eggs, the bubbles escaping through the outlet tube. The central tube is now restored to its former position. The automatic action permits entire separation of bad from good eggs, though some days may be required to accomplish the full result. The dead become lighter from gases arising from decomposition. A net, small enough to easily enter the mouth of the jar and fixed to a handle several inches longer than the jar, is convenient for removing particles of foreign matter.

Shad eggs are semi-buoyant, and those which will not rise commence lumping on the third or fourth day. The usual period of hatching is from 6 to 10 days, sometimes longer, according to temperature of water, but with high temperature they will hatch in 3 days. Fry hatched in less than 5 days are usually, though not always, weak. In general, the period of incubation varies inversely with the prevailing temperature, but continuous dark and cloudy days will retard and strong light will accelerate development under precisely the same conditions of water temperature, and other circumstances not well understood may also have their influence.

Fry when hatched are about 0.37 inch long. They have been measured at intervals of from 5 to 15 days, from late in May to the middle of October. Toward the middle of August the rate in growth diminishes. When 9 days old they are about 0.62 inch long. Fry 0.5 inch long July 20th were 0.75 inch long 8 days later; on August 14th, 2 to 2.25 inches; September 20th, 3 to 4 inches; October 1st, 4 to 4½ inches; November 4th, 5 to 7 inches. Some years they grow faster than others, and in some streams more rapidly than in others. From the State fish-ponds at Raleigh, North Carolina, 33 were removed in November, 1884, which measured 8 to 9 inches. Their usual size in the Potomac in the fall is 3 to 4 inches.

MEASURING THE EGGS AND FRY.

To estimate the number of eggs and of the young fry was for years rather a difficult matter to accomplish satisfactorily. The standard made use of at the outset was undoubtedly much too high. The scale most used at present is a light square, made of wood, the longer leg being 15 inches and the shorter 7½ inches long. The material is ½ inch wide and ¼ inch thick. The graduations are on the longer leg, and read from the lower end upward. The first line is at a height corresponding to the level attained in the jar by a measured half-pint of water, and the succeeding lines are determined by the introduction of additional half-pints of water. When the scale is being constructed, the central glass tube is stopped at the lower end that it may displace an amount of water equal to the amount of eggs it will displace in

practice. Each line on the measuring stick registers 7,000 shad eggs. The number of eggs in a liquid pint is established by actual count. Those which are very young or have been lately on trays are not of normal size and not qualified for measurement. The eggs are at rest when measured.

The jar contents are determined by placing the short leg of the measuring-stick over the top, with the other pointing downward and touching the side of the jar. The number is indicated on the scale at the point opposite the surface of the bulk of the eggs. Scarcely any semi-buoyant eggs die, under proper conditions, after hatching out has commenced, and a close approximation to the number of fry may be obtained from the last measurement, which is made after the careful removal of all dead eggs and the bursting forth of the first young.

Application of a measuring scale to a jar of shad eggs.

FEEDING AND REARING.

The young shad swims vigorously, by rapid and continuous vibration of the tail, from the moment it leaves the egg. It is colorless, transparent, and gelatinous. Several hundred in a dipper are scarcely discernible. It has a relatively large yolk-sac, but supports it with ease during the first four or five days after hatching, the small quantity remaining after this time not being visible externally, although found in shad fry 14 to 16 days old. Minute conical teeth make their appearance on the lower jaws and in the pharynx about the second or third day after hatching. The jaws at three months are armed with teeth slightly curved.

Young shad feed on other minute organisms, such as exceedingly small crustaceans. Food has never been observed in the alimentary canal until ten or twelve days after the young fish had left the egg. At about the middle of the second week considerable may be seen, but the intestine is then not often very densely packed. At the age of three weeks an abundance of food is found. They have been known at this early age to eat their own kind, and later the young carp and salmon. When cold, raw winds drive the crustaceans into deeper water, the young shad follow them, and in aquaria they take crustacea freely. In salt-water aquaria they may be fed upon chopped oysters and canned herring-roe.

Experiments with young shad have been carried on for several years at Central Station in salt-water aquaria. On one occasion about 250 were received in October, at which time they were about five months old. They were put in brackish water, specific gravity 1.005, which

was added to from day to day for nearly a week, when it was brought up to 1.018, or the same specific gravity as the water used in the marine aquaria. At the time these were placed in the brackish water others were put into fresh-water aquaria, but the latter died within three days. Those in salt water began in two or three days to take food, consisting of chopped oysters, clams, and beef, the preference being for oysters. At first they would take food only when it was sinking, later they began taking it off plants where it had lodged, and finally from the bottom. Nearly all remained healthy, plump, and active for six months, some living until about midsummer.

For ten years past two or three million shad fry have been reared annually at the Fish Ponds, Washington, D. C. A 6-acre pond is used, the water supply being taken from the city water-works. The depth varies from 2 to 3 feet, and throughout the whole extent there is a dense growth of water-plants, among which crustacean food multiplies—new supplies being brought in from the water-pipes. Fingerling shad are so tender that the numbers annually liberated can not be ascertained; they can not withstand the handling consequent upon counting them, not even undergoing transfer in dippers of water, and their scales drop off on being touched; consequently at high tide they are liberated into the Potomac through a sluice-gate with an outlet pipe about 2 feet in diameter. They require some days to make their escape. By conservative estimate 50 to 60 per cent are held safely until about October.

Rearing has been experimentally tested at Wytheville and Neosho with good results. At Neosho on the 3d of June, 1892, 700,000 fry were received from Gloucester, N. J.; their growth was satisfactory. In preparing for their release the hatchery branch was cleared of shoals, drifts, and aquatic plants for three-quarters of a mile, and early in November, when the branch was swollen with rain water, 200,000 6-months-old fish were allowed to pass through open gates; they were some hours in escaping, in a continuous silvery mass. These were the first fingerling shad planted in waters tributary to the Gulf of Mexico.

TRANSPORTATION.

Good, healthy fry will pass from the jar to the collector-tank as fast as hatched, and unless too thick will not lie on the bottom of the tank, although they sometimes crowd on the side nearest the strongest rays of light. As many as 500,000 to 800,000 are collected in each tank. In transporting, they must be kept in vessels with smooth surfaces, preferably tin-lined cans. Zinc vessels are destructive, and galvanized cans are not recommended.

About 2,000 to 3,000 fry are put to a gallon of water, which must be pure enough for ordinary drinking purposes and well aerated. The water in the cans must be kept at 58° to 65°, though in rivers and ponds the fry endure a temperature of 90° F.

As early as 1874, experiments were carried on to retard the development of eggs, in order to provide a longer period between the delivery

of the eggs from the parent fish and the absorption of the yolk-sac. Eggs, when transported, were placed on trays and put under melting ice, and later experiments have been conducted inside refrigerator boxes.

Pathological changes or deformities are induced in the embryos when subjected to too low a temperature or when held long enough on damp flannel trays (ordinary air temperatures) to hatch.

It would appear that 55° to 53° is the lowest temperature in which ova will safely undergo their normal development and 9 days is the longest period of incubation attainable at that temperature—time sufficient, when added to the several days required for the young to absorb the yolk-sac, to ship them to Europe, though efforts in this direction have thus far failed. One drawback is the rapid development of fungus, which grows over the eggs, penetrates the membranes, and kills the ova.

The eggs are shipped in crates of 20 shallow trays, the frames of the latter being of wood with bottoms of wire mesh about 8 to the linear inch. Wood and wire are painted with asphaltum. Each tray is covered with cheese-cloth, somewhat overlapping the edges, the cloths being hemmed, to avoid ravelings. There are two frames of wood, connected with leather straps; one the base and the other the cover for the stack of trays. The trays, after being filled with eggs, are wrapped in a long, cotton-goods apron and strapped together. There is an iron handle on the top frame, and the lowermost tray is put down empty with the wire surface upward. Then follow the trays containing eggs, the uppermost one being put on empty with the wire surface up. The top and bottom trays are merely to protect the others.

The greater part of the water above the eggs is poured off from the jars and the remainder poured into tin pans along with the eggs. The cloths, after soaking in water, are arranged one by one on the trays and tucked closely into the four corners. The trays are stacked up and eggs poured evenly over the surface of the top one with a large dipper, and each tray, when filled, is put on the crate base. The surplus water drains away to the manipulating table. Tray cloths, which are made of material too closely woven to let the water through are unsuitable.

The eggs are bailed up in dippers with the water that they are in, and usually spread two layers deep, but may be put on more thickly. When eighteen trays are filled they are wrapped in the outer cloth, previously soaked in water, and tightly buckled together. The crate covers and tray cloths are boiled in water each time after use.

Each tray—14 by 19 inches area, with two layers of eggs—holds about 20,000 eggs, the contents of a full crate representing from 300,000 to 400,000 eggs. While in transit the crates are sprinkled with river water on the sides at least once an hour, and kept in the shade, away from the cooling influence of the wind, to preserve even temperature.

TRANSPLANTING.

The propagation of shad is mainly carried on to maintain or increase the supply in rivers where the species is native, but this fish has also been planted in waters in which it was either unknown or found in small quantities. Large numbers of fry have been liberated in tributaries of the Gulf of Mexico, but without marked results. Between 1873 and 1892 several million fry were experimentally placed in Great Salt Lake, Utah Lake, and Bear Lake, Utah; and from 1884 to 1886, 3,000,000 fry were liberated in the Colorado River at the Needles, in Arizona, but these experiments were unsuccessful.

Remarkable success has, however, attended the stocking of the waters of the Pacific coast. In 1871, 12,000 shad fry from the Hudson River were liberated in the Sacramento River by the California Fish Commission, and in 1873 the United States Commission made a second deposit of 35,000. Subsequent plants in the Sacramento, aggregating 609,000, were made by the United States Commission from 1876 to 1880. From these small colonies, amounting to less than 1 per cent of the number now annually planted in the Atlantic Slope rivers, the shad have multiplied and distributed themselves along nearly 3,000 miles of the coast from southern California to southeastern Alaska. They reached Rogue River, Oregon, in 1882. In the Columbia a few were taken as early as 1876 or 1877. About 1881 or 1882 they were on the coast of Washington, reaching Puget Sound in 1882. They appeared in the Fraser River, British Columbia, in 1891; in the Stikine River, near Wrangell Island, Alaska, the same year, and are now found along the entire coast from Los Angeles County, Cal., to Chilkat, Alaska, covering 22 degrees of latitude. Their distribution, from the standpoint of commercial importance, is from Monterey Bay to Puget Sound.

On the northern part of the coast the first shad fry were introduced in 1885, the number being 60,000. Of these, 50,000 were put in the Willamette River and 10,000 in the Snake River. The following year 850,000 were introduced into the Columbia River.

The shad is now one of the most abundant fishes of California. As a result of the liberation of the first two consignments, adult shad were caught in 1874, and by 1876 this fish had become numerous. In 1880 specimens of all sizes were taken in the Sacramento River and Monterey Bay, and it was evident that the shad had begun to multiply, its increase up to 1883 being marvelous. It is most numerous on the west coast in San Francisco Bay and its tributaries, where, contrary to its habits in Atlantic waters, it is found throughout the year. It is not common above Sacramento, owing to the low water temperature. In the Columbia it is regularly found as far as the Cascades, about 150 miles above the mouth of the river.

U. S. COMMISSION OF FISH AND FISHERIES.

GEORGE M. BOWERS, Commissioner.

ARTIFICIAL PROPAGATION

OF THE

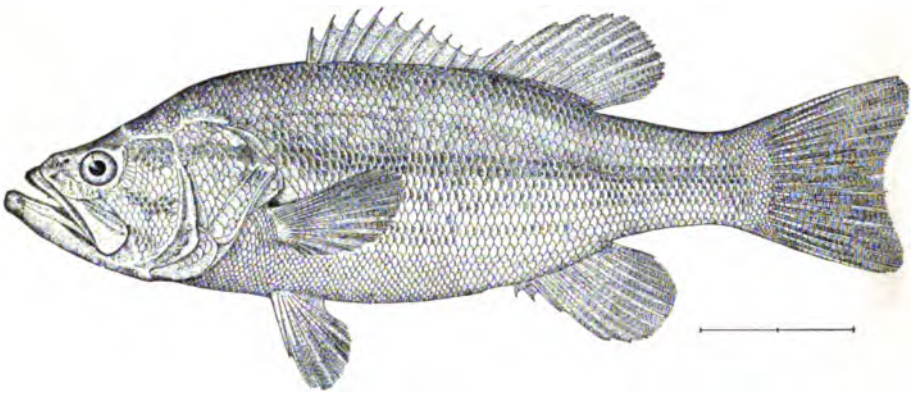
BLACK BASSES, CRAPPIES,

AND

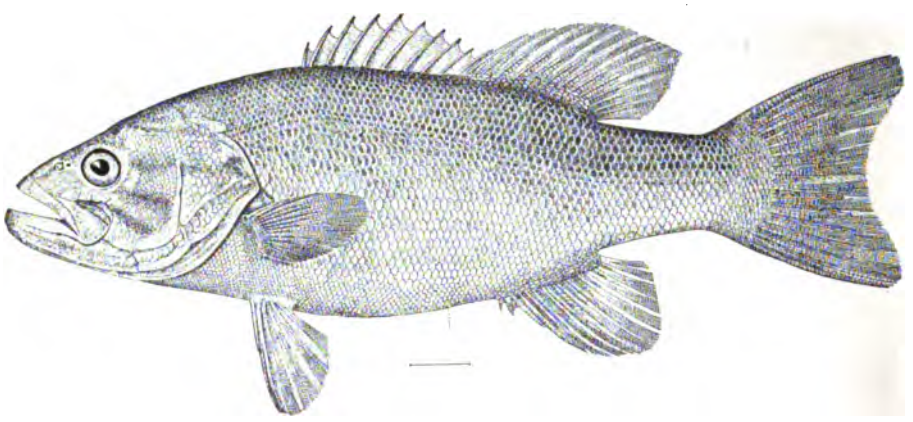
ROCK BASS.

Extracted from the Revised Edition of the Fish Manual. Pages 147 to 163, Plates 47 to 50.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.



MICROPTERUS SALMOIDES. *Large-mouthed Black Bass.*



MICROPTERUS DOLOMIEU. *Small-mouthed Black Bass.*

THE BLACK BASSES, CRAPPIES, AND ROCK BASS.

DESCRIPTION OF THE FISHES, COMMON NAMES, ETC.

The species treated of in this chapter are those members of the *Centrarchidae* (or fresh-water sunfishes) which have come under the scope of fish-culture, namely, the large-mouth black bass (*Micropterus salmoides*), the small-mouth black bass (*Micropterus dolomieu*), the rock bass (*Ambloplites rupestris*), the crappie (*Pomoxis annularis*), and the calico bass (*Pomoxis sparoides*). Whatever is said of the rock bass will apply equally well to other sunfishes, which might be here considered but which have not been artificially reared.

The principal physical characters of these fishes are indicated in the following key, which serves to distinguish the two species of black bass and the two species of crappie from each other as well as from less closely related species.

Large-mouth black bass: Body comparatively long, the depth about one-third the length; back little elevated; head large, 3 to 3½ in body; eye 5 to 6 in head; mouth very large, the maxillary in adults extending beyond eye, smaller in young. Ten rows of scales on the cheeks; body scales large, about 68 in the lateral line, and 7 above and 16 below the line. Dorsal fin low, deeply notched, larger than anal, with 10 spines and 12 or 13 soft rays; anal with 3 spines and 10 or 11 rays. Color above dark-green, sides greenish-silvery, belly white; young with a blackish band along sides from opercle to tail, the band breaking up and growing paler with age; caudal fin pale at base, white on edge and black between; older specimens almost uniformly dull greenish; three dark oblique stripes across opercle and cheek; dark blotch on opercle.

Small-mouth black bass: Similar in form to large-mouth bass. Mouth smaller, the maxillary terminating in front of posterior edge of eye, except in very old specimens. About 17 rows of small scales on the cheeks; body scales small, 11–74–17. Dorsal fin less deeply notched than in other species, with 10 spines and 13 to 15 rays; anal with 3 spines and 12 or 13 rays. General color dull golden-green, belly white; young with dark spots along sides tending to form irregular vertical bars, but never a lateral band; caudal fin yellowish at base, white at tip, with dark intervening area; dorsal with bronze spots and dusky edge; three radiating bronze stripes extending backward from eye; dusky spot on point of opercle.

Crappie: Body short, greatly compressed, back much elevated; depth

2⅓ in length; eye large, one-fourth length of head; head long, 3 in length; profile with double curve; mouth large, snout projecting. Scales on cheeks in 4 or 5 rows; scales in lateral line 36 to 48. Dorsal fin smaller than anal, with 6 spines and 15 rays, the spinous part the shorter; anal with 6 spines and 18 rays; dorsal and anal fins very high. Color silvery white or olive, with mottlings of dark green; the markings mostly on upper part of body and tending to form narrow, irregular vertical bars; dorsal and caudal fins with dark markings; anal nearly plain. The figure of this species on the opposite page is scarcely typical in the pattern of markings.

Calico bass: Similar in form to crappie, but the body shorter, back more elevated, and profile of head straighter; depth, one-half length; head one-third length; mouth smaller than in crappie; snout less projecting. Six rows of scales on cheeks, and 40 to 45 along lateral line. Dorsal and anal fins higher than in crappie; dorsal spines 7 or 8, rays 15; anal spines 6, rays 17 or 18. Color light silvery-green, with dark-green irregular mottlings over entire body; dorsal, caudal, and anal fins with dark-olive reticulations surrounding pale areas; whole body sometimes with a delicate pink reflection (whence the name strawberry bass).

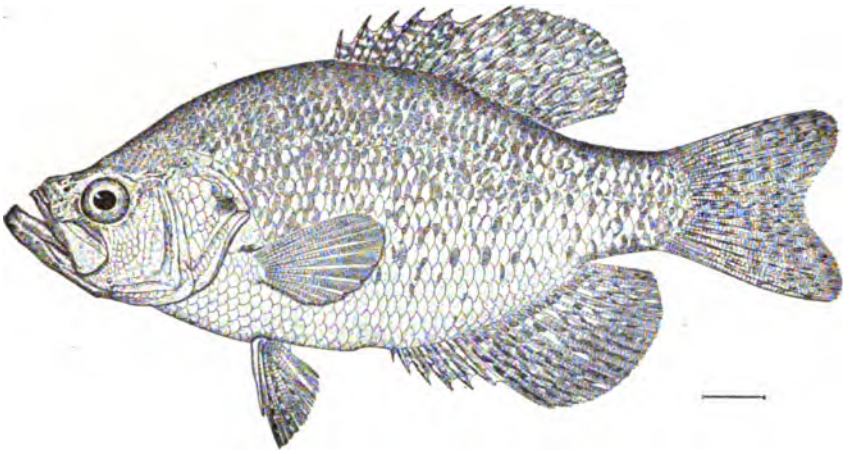
Rock bass: Body oblong, compressed, back moderately elevated; depth 2 to 2½ in length; head large, 2¾ in length; eye very large, 3½ in head. Scales 5–39–12, in 6 to 8 rows on cheeks. Dorsal fin much larger than anal, with 11 spines and 10 rays; anal, with 6 spines and 10 rays. Opercle ending in two flat points; gillrakers less than 10. Color olive-green, with brassy reflections; young irregularly barred and blotched with black; adult with a dark spot at base of each scale, forming interrupted and inconspicuous stripes; a black spot on opercle; anal, caudal, and soft dorsal fins with dark mottlings.

The most reliable character for distinguishing the large-mouth from the small-mouth bass is the number of rows of scales on the cheeks. The colors of each species vary with age and the size of the mouth varies with the size of the fish, but the scales are constant under all conditions. With the crappies, the leading differential feature is the number of dorsal spines.

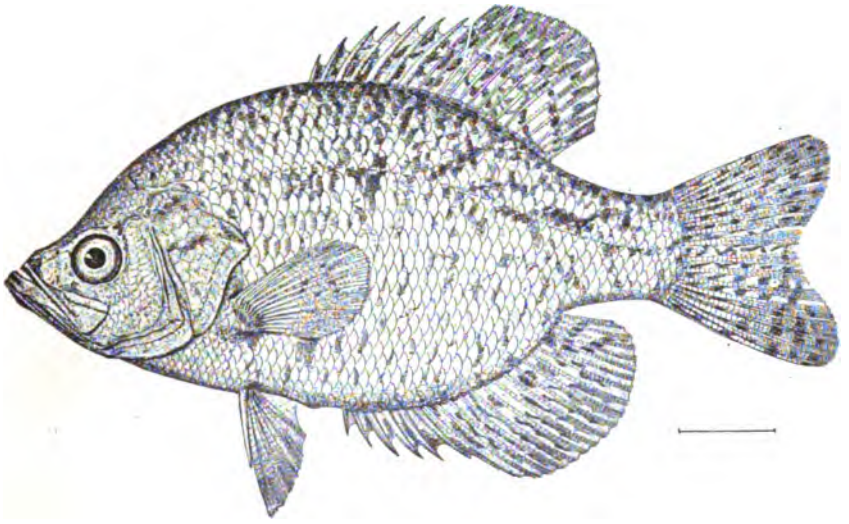
By reason of their wide geographical range, the black basses have received a multiplicity of popular names. The large-mouth black bass is known as Oswego bass, lake bass, green bass, yellow bass, moss bass, bayou bass, trout, jumper, chub, and welshman. In the North it is generally called black bass; in Virginia and North Carolina it is usually designated as the chub, and in Florida and the Southern States it is often called trout. The small-mouth black bass has received the common names of lake bass, brown bass, ninny bass, hog bass, black perch (used in the mountain sections of Virginia, Tennessee, and North Carolina) trout perch, brown trout, jumper, mountain trout, together with other names of purely local use.

Rock bass are variously known as red-eye, red-eye perch, and goggle-eye, and are sometimes confounded with the warmouth (*Chænobryttus gulosus*), which bears some of the same common names.

The calico bass has also received the names of strawberry bass, grass bass, bitter-head, barfish, lamplighter, goggle-eye, goggle-eye perch, speckled perch, and speckled trout. The crappie is known in its native waters as crappie, new light, campbellite, sac-a-lait, bachelor, chinquapin perch, croppie, and cropet. On account of the similarity of the



POMOXIS ANNULARIS. *Crappie.*



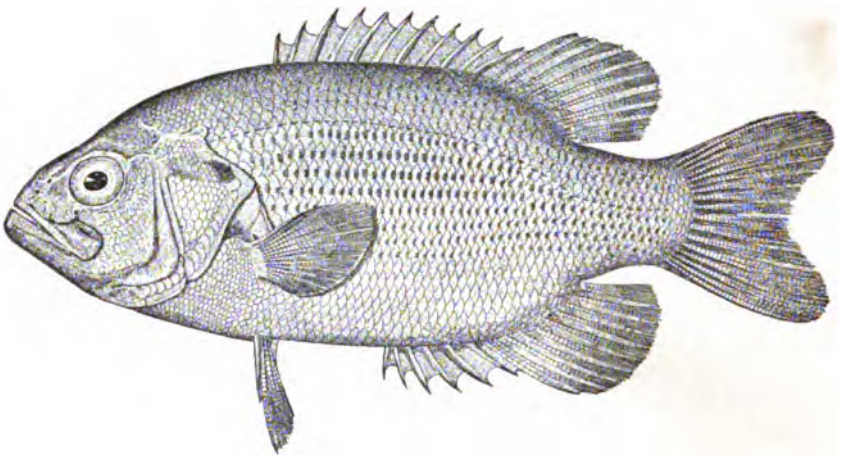
POMOXIS SPAROIDES, *Calico Bass, Strawberry Bass.*

calico bass and crappie, anglers and fish-culturists frequently confound the two, the common and local names often being used interchangeably throughout the regions to which both are native.

Possibly no common name of the black bass is more appropriate than "jumper" which is applied in certain parts of Kentucky. It is difficult to capture them with a seine rigged in the ordinary manner, especially

when they have the vitality and activity which is usual when living in water of moderate temperature, and in collecting brood stock it is well to use a seine about three times the depth of the water, as the bagging of a seine so rigged confuses the fish and deters them from jumping. While the black bass of the colder northern waters make a fight worthy of the salmon, they may be taken from the waters of the south with hardly a struggle.

Rock bass are exceedingly pugnacious, and sometimes seem to take the hook rather on this account than from a desire for food. They are well adapted for pond-culture, and under proper conditions will repay the culturist in a large crop of young with the expenditure of very little labor and time.



AMBLOPLITES RUPESTRIS, *Rock Bass.*

The calico bass is a fairly game fighter, and its firm, white flesh has a fine flavor when the fish is taken from cool, pure waters; but it is a very delicate fish to propagate artificially. It seems to resent captivity, and especially when taken from warm waters is exceedingly tender, quick to yield to attacks of fungus, and liable to become blind and die. Of large numbers collected and transplanted in new waters many have died within a few days after being deposited.

The spawning and breeding habits of the calico bass and the crappie are so nearly like those of the rock bass that special remarks on the subject do not appear necessary.

GROWTH AND WEIGHT.

There is a wide difference in the rate of growth, and there is no way by which the age of a black bass can be determined from its size. Some are comparatively large from the moment they are hatched, and grow much more rapidly than the smaller members of the same school. The average size of adults varies in different localities, and may vary from year to year in any particular locality. The variations depend upon initial vitality, upon the scarcity or abundance of food, and upon

the range and space given the fish. At the age of 5 or 6 months the young bass measure from 4 to 8 inches, according to locality and surroundings, though a few individuals are apt to run larger. In 1892, at Neosho station, a black bass, which was positively known to be under 18 months old, weighed on the scales 1 pound 9½ ounces.

The large-mouth bass have been known to weigh 23 pounds, and a 6-pound or 8-pound bass in the southern tributaries of the Mississippi and in the inland lakes of Florida excites no surprise. The small-mouth bass does not grow so large, 2½ pounds probably exceeding their average size, though they occasionally reach 5 or 6 pounds. The rock-bass fry grow slowly, those 6 months old seldom averaging 2 inches in length. The adult usually weighs from ½ to ¾ pound, occasionally reaching 1 pound; and examples have been recorded as high as 3 pounds.

The crappie and the strawberry bass will, as a rule, not exceed 1 pound in weight, though in Missouri the former has been taken as high as 3 pounds. With similar environments, at 6 months old the young of both these species are about the size of black-bass fry of the same age, possibly a little smaller. Each school will have a few individuals much larger than the majority.

NATURAL HABITAT AND DISTRIBUTION.

The large-mouth and small-mouth black basses are widely distributed. The large-mouth is indigenous from the Great Lakes and the Red River of the North to Florida, Texas, and Mexico, and west to the Dakotas, Nebraska, and Kansas. The small-mouth bass ranged formerly from Lake Champlain to Manitoba, and southward on both sides of the Alleghenies to South Carolina and Arkansas. The adaptability of these fish to extremes of temperature and their great tenacity of life under seemingly adverse conditions have made their distribution comparatively easy, and they have been successfully introduced into nearly all the sections of the United States to which they were not native, and into England, France, Germany, and Finland. They have been planted in California, Washington, Utah, and other Western States by the U. S. Fish Commission. In three years they became so numerous in Utah that 30,000 pounds were caught and marketed from one lake.

Two notable early instances of the successful transplanting of black bass in a primitive way may be mentioned, the fish being transferred in the tender of a locomotive—once in 1853, when the Potomac was stocked, and again in 1875, when, under the direction of the Commissioner of Fisheries of Virginia, adult black bass were removed from the Roanoke River across the divide to the New River, a tributary of the Kanawha. Up to 1875 the Kanawha contained no bass, and its edible fishes consisted almost entirely of catfish, but for the past ten or a dozen years thousands of bass have been taken from New River and its numerous tributaries, draining ten counties of Virginia and running through parts of North Carolina and West Virginia. New River was also successfully stocked with rock bass by the Virginia Fish Commission, the fish being brought from Holston River, a tributary of the Tennessee in

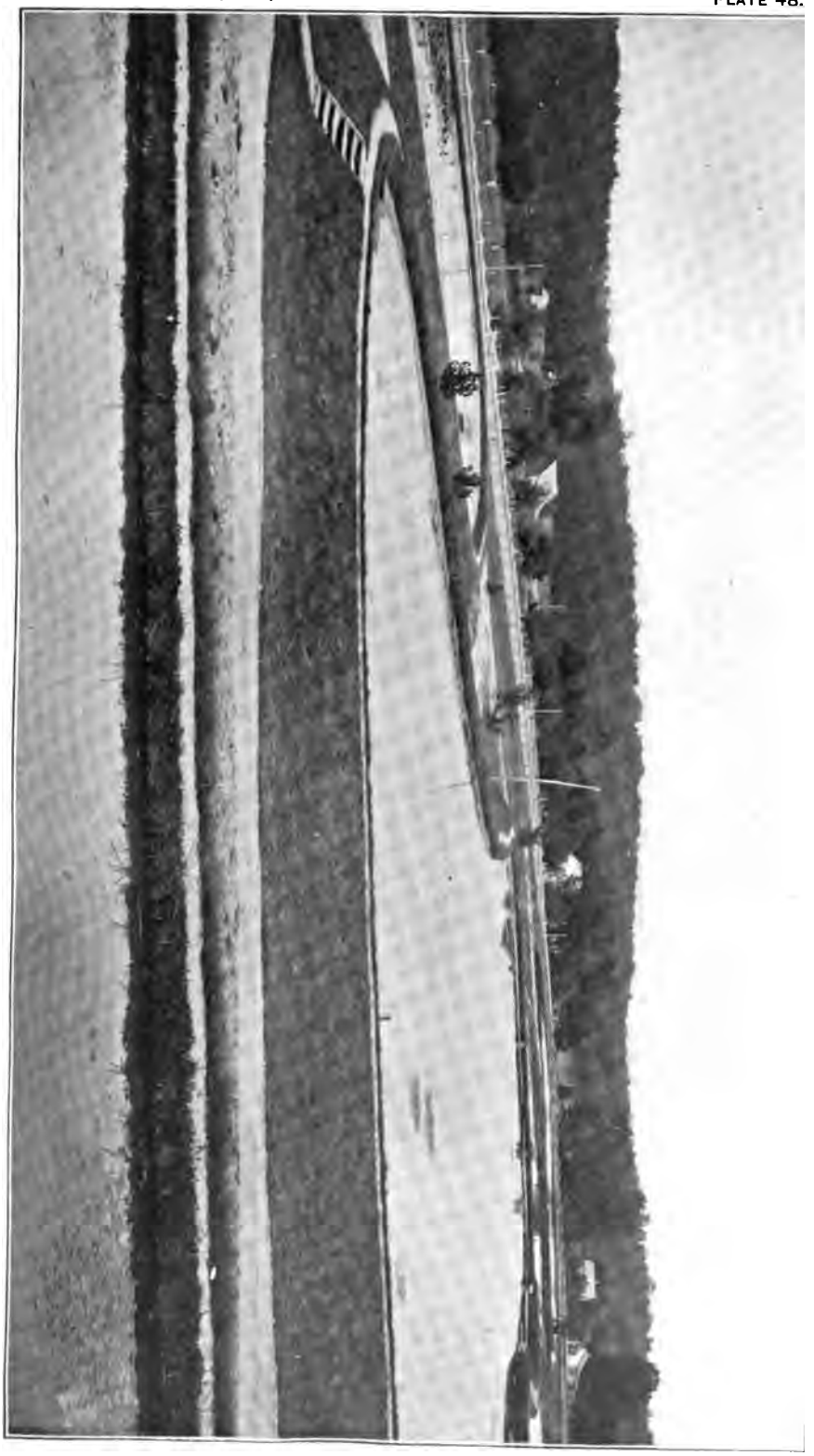
Washington County, Virginia, in June, 1876, and deposited in the smaller tributaries of New River, in Montgomery County, Virginia, whence they have colonized the entire New River basin.

Few fish thrive in water of such extremes of temperature as the large-mouth black bass, and, to some extent, the small-mouth. The former are found in water covered with ice and in that standing at 100° F.; but with both species sudden changes of temperature are apt to prove fatal.

The small-mouth black bass seeks pure, rapid, fairly clear streams, and lives at higher elevations and in clearer waters than the large-mouth. In the northern part of its range it becomes torpid in winter, but in the warmer waters of the South it is active throughout the year. The large-mouth black bass also likes pure, clear water, but often inhabits the hot and stagnant bayous and ponds of the South. It has been seen in great numbers under conditions of high temperature and muddy water which would ordinarily be fatal to all forms of aquatic life except of a very low order. Many die in such cases, but numbers live for months and some possibly for years. Those from hot, stagnant waters, however, have a soft, flabby flesh, and are apt to be infested with parasites; they spoil quickly and are not palatable. They do not voluntarily seek such unfavorable surroundings, their presence there being attributable to accident. The bass thus found in the Mississippi Valley have been left by spring freshets, and, failing to go out with the slowly receding waters, they reproduce in great numbers in the ponds and lakes temporarily formed in depressions of the land. The neighboring areas are usually either rich alluvial meadows or swampy forests, from which the receding water drains an infinite quantity of natural food for the sustenance of the fish retained in the temporary ponds.

The rock bass is indigenous to the Great Lakes region and Mississippi Valley, and there is evidence to show that it is native to certain streams on the east side of the Alleghanies. It has been successfully introduced into many new waters. In its native waters it is found in the winter months under ice, yet it stands a high summer temperature, though not so great as the black bass. The highest temperature to which it has been subjected at Neosho is 88°. In transportation this species seems to suffer from change of temperature as quickly as the black bass, with possibly this difference, that while the black bass seems to be more quickly and fatally affected by a change from high to low temperature, the opposite change more quickly and injuriously affects the rock bass. Though sometimes found in muddy bayous and in waters stained by decaying vegetation, the rock bass thrives better in clear, pure waters well stocked with aquatic plants.

The natural habitat of the calico bass is the Great Lakes region, the entire Mississippi Valley south to Louisiana, and the streams of the Carolinas and Georgia east of the Alleghanies, while its close kin, the crappie, is confined to the Mississippi Valley, though sometimes taken in the Great Lakes region. The calico bass is said to need a higher temperature and clearer water than the crappie, but this is not certain.



BASS PONDS AT NEOSHO STATION.

NATURAL FOOD, ETC.

The natural food of the black basses varies greatly and is influenced by the spawning season, character and temperature of the water, and the weather. The adults are voracious and pugnacious, and devour other fish almost indiscriminately; their food comprises crawfish, minnows, frogs, tadpoles, worms, and mussels, while the young feed on insects and other minute forms of life found in water.

At times both the large-mouth and the small-mouth bass refuse the most tempting bait, and at other times they bite greedily at almost everything. Various kinds of animals of a suitable size, even rats and snakes, and many varieties of vegetables, have been found in their stomachs, and in a wild state under some conditions they devour almost anything moving in or immediately over the surface of the water.

The black basses afford perhaps the highest type among fishes of parental care and watchfulness, guarding their young until after the dispersal of the school of fry; but many of the young, so zealously protected early in the season, subsequently furnish food for adult bass, possibly their own progenitors. As with trout, bass of the same school of young vary in size, and the larger prey mercilessly on the weaker, often attacking their own kind, even when other natural food is abundant.

COMMERCIAL IMPORTANCE.

The market value to the fishermen of the black bass taken in the United States amounts to about $130,000 annually, a sum representing over 2,000,000 pounds of fish. A large part of the bass caught, however, never reaches the market, being consumed by anglers and their friends. The indirect value of bass fishing to rural districts, in the expenditures of visiting sportsmen for boats, guides, teams, supplies, and accommodations, is very great.

Ten years ago it was said that black bass did not exist in sufficiently large numbers to ever become a staple article of food, but they now furnish important additions to the food supply of many thousands of people. The annual sales in New York City are estimated to be at least 50,000 pounds, with an average value of 10 cents per pound. The States in which the black-bass fishery is most important are North Carolina and Ohio; in 1897, over 535,000 pounds, valued at $23,600, were caught for market in North Carolina; in Ohio, nearly 300,000 pounds, worth over $22,000, were taken. Other States, in which there is an annual yield of over 100,000 pounds, are Arkansas, Florida, Minnesota, Missouri, and New York, and in about twenty other States this fish is of some commercial importance. The fishermen of Illinois ship nearly 50 tons of black bass to the markets annually.

The annual catch of crappie for market, according to recent statistics, is about 850,000 pounds, having a first value of $39,000. The leading States in this fishery are Arkansas, Illinois, Minnesota, Missouri, and Tennessee, the three first named producing more than half the yearly yield. The market value of the rock bass is not large. Crappies are generally considered better food-fish than the rock bass and enter

much more largely into commerce. As with black bass, a very large percentage of the catch of crappies, rock bass, and sunfishes does not reach the markets.

LIMITATIONS OF BASS-CULTURE.

Unlike the shad and salmon, the artificial propagation of black bass, by taking and impregnating the eggs, has not been, up to the present time, practically successful. The eggs can only be stripped with great difficulty, and it has been necessary to kill the male to obtain the milt. Another obstacle is the difficulty of obtaining eggs and milt at the same time, even when the fish are taken from over the nests apparently in the act of spawning. Interruption or handling seems to prevent the discharge of eggs or milt. At Neosho unsuccessful efforts were made daily for several weeks to spawn a female black bass which was so near the point of spawning that when held head downward the eggs could be seen to roll forward toward the head, and when reversed to drop in the opposite direction.

Since a practicable way to artificially impregnate the eggs of the bass has not yet been developed, and the handling of eggs with indoor apparatus is impossible, it is fortunate that the natural impregnation of these fishes reaches a percentage closely approximating that which fish-culturists have been able to secure by artificial means from other species, and also that the parental instinct is unusually developed. The first conditions make pond-culture necessary, and the second render it possible. The methods hereafter described are those in use at Neosho station.

ARTIFICIAL PONDS.

The size of spawning-ponds for rearing bass depends largely on the amount of land available, its topography, and the water supply. Ponds not less than ½ acre in area, with the inlet at one end and the outlet at the other in the line of the longest axis, generally produce the best results, though smaller ponds have been successfully used.

At least one-fourth of the pond should be not over 1 foot in depth, and this portion should be planted with pond-weed (*Potamogeton*) and water-weed (*Elodea* or *Anacharis*) to facilitate the production and growth of the minute animals which furnish so large a part of the food for the young bass. The rest of the pond should have a gradually sloping bottom and a consequent increase of depth to the kettle (or draw-off), where the water must be at least from 5 to 6 feet deep for the warm Southern States, and 8 to 10 feet deep for the Northern States, to provide against the danger of freezing. In the middle third of the pond water-lilies should be planted, preferably those with large pads, such as *Nymphea alba;* these plants not only furnish the breeding fish a hiding-place from fish-hawks, but serve as sunshades during the summer. It is not advisable to place large bowlders in the pond, as they are in the way of seining or netting and furnish an acceptable resort for crawfish.

Nursery ponds should be constructed to afford young bass protection from enemies and to produce the greatest quantity of insect life suited to their sustenance, and this is better accomplished with a number of small ponds than with one large one. A good working size is from 40 to 50 feet long by 12 to 15 feet wide, with a depth of from 30 to 36 inches for the "kettle." Where the topography of the ground will permit, it is best to have the nurseries immediately adjoining the spawning-pond, with the water supply from the same source, so that there will be but slight difference between the temperature of the shallowest part of the nursery-pond and the surface water of the other.

The young large-mouth bass is not a strong fish, and currents in the spawning and nursery ponds should be avoided for some time after the spawning period.

If the locality is infested with crawfish, it is advisable to pile or otherwise protect the banks; and the entrance of snakes, frogs, and such enemies may be prevented by surrounding the pond with finely woven screens, or, better yet, boards let into the earth a few inches and projecting above the ground. The pond should be supplied with the aquatic plants previously mentioned as desirable for the shallow parts of the spawning-pond.

A spawning and nursery pond may be combined by constructing one comparatively long pond, narrow near the middle, so that the general shape will be like a dumb-bell with a very short handle. Across the narrow part is to be stretched a screen of one-fourth inch wire cloth, which will confine the spawners to the deeper end of the pond, while the fry, following their instinct of moving upstream, will find their way through the screen into the upper shallower end. This form of pond is advantageous where for any reason only a few ponds can be built.

In addition to the nursery ponds, tanks 6 feet wide and 10 to 12 feet long and 5 feet deep, made of cement and brick, or wood, should be provided for holding the fish preparatory to shipment during the fall, and are also very convenient for handling the fry when they are being transferred from the spawning to the nursery ponds prior to being assorted as to size. At Neosho, where the fry are removed from the spawning-ponds at a very early stage, they are held in troughs similar to those in general use for trout culture. A trough 14 feet long with 4 inches depth of water at 57°, changing 2 gallons per minute, will support from 3,000 to 5,000 very young fry, and twice or three times as many rock bass will live comfortably under like conditions. The same general care and cleaning usually given to troughs containing trout fry is necessary in cultivating bass. The trough should be swept down twice a day and occasionally washed inside with a cloth, and the water supply, conduits, and outlets frequently examined and kept clear and clean.

The young bass is able to stand any temperature to which the sun raises the water of the nursery; those hatched in water at 56° F. will thrive two months later with the temperature at 86°. But bass grown in a very high temperature are exceedingly tender, and can not be

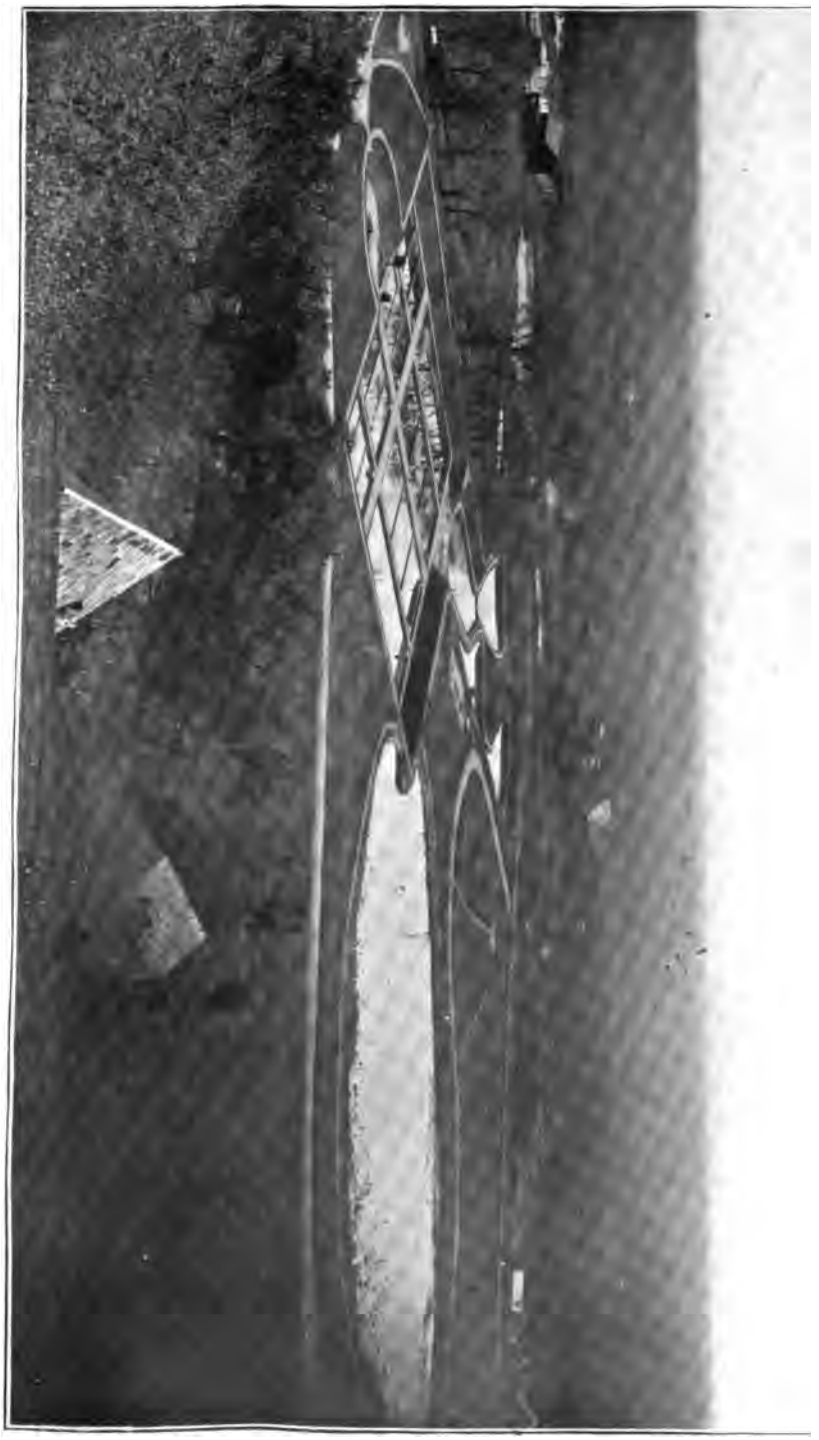
handled and transported until the approach of fall and winter has gradually reduced the temperature and thus hardened them; they are also more liable to attacks of parasites, both external and internal. While bass can live in water ranging from 33° to 98°, more moderate limits are desirable. The *Cyclops* and some other of the natural forms of food for young bass reproduce best at a temperature between 68° and 70°, and can not resist higher than 95°.

CARE OF PONDS.

It is desirable that the ponds should be "wintered" each year—that is, entirely drawn off in the autumn, thus leaving the beds exposed to the combined action of sun, winds, and frost. This tends to kill out the larvæ of the larger aquatic insects (dragon flies, beetles, etc.), and to increase the following season's supply of small crustacea, which furnish an important element of food to the young bass. This purifying process can be assisted by the free use of quicklime dropped into the crawfish holes. There is no danger of the lime injuring the fish the following year, and the limewater purifies the pond bed, besides killing the crawfish and the like.

The accumulated decayed matter ought to be occasionally removed, the frequency for this depending on the character of the water supply, the amount of silt it brings into the pond, the character of the soil, and on the thoroughness of the yearly removal of the surplus vegetation. Scraping large ponds and hauling the accumulated muck involve considerable labor and expense, possibly more than the yield of the pond warrants, and in some cases it is advisable, once in four or five years, to lay the pond bare for an entire year and cultivate it in peas or some other deep-rooted vegetable.

While abundant pond vegetation is favorable to a large production of fry, it is sometimes so luxuriant that it settles down in a blanket-like mass and smothers many of the young fish. Under such circumstances it should be removed some time in advance of lowering the pond level, and during the process should be carefully picked over, as some of the fry will be found among it. Wading into the pond leaves the bottom tracked with deep footprints, which, as the water recedes, catch and retain many of the young fishes, most of which die in a short time. To avoid this a strong but lightly built flatboat is used, which can easily be moved from pond to pond, as needed. At each end of the boat is a ring, through which a stake is driven at the point in the pond to be worked. The vegetation is raked from the water in small lots, and unloaded on the banks with a pitchfork. It should be promptly removed from the bank, as it will rot very fast and its presence is objectionable. At the Texas station, where the vegetation is very luxuriant, it is hauled to the banks with a long rake 8 feet wide, operated by two men, and is then removed by means of long-handled forks. This method is simple and very economical, two men accomplishing more than five or six by the other method.



BASS PONDS AT SAN MARCOS STATION.

NESTS AND NEST-BUILDING.

Whenever the spawning period occurs, whether early or late, ample warning is given by the preparation of the nests, which are built by the mated fish, sometimes working in company and sometimes separately. In the Great Lakes region and the North and Middle Atlantic States the nests are ordinarily built of gravel, brushed into neat circular piles 18 to 36 inches in diameter, and are usually found in water from 18 to 36 inches deep, though not infrequently in much deeper water and sometimes in water less than a foot in depth.

In the proper preparation of the newly-built spawning-pond clean gravel, ranging in size from a buckshot to a hickory nut, is arranged in small flat heaps about 4 to 6 feet from the banks, as soon as the ice is off in the spring, in advance of the spawning season, and, if well located, it can be used through several seasons and more than once in the same season. Gravel probably possesses no advantage of itself over a hard-clay bed except that it presents more surface within a given area for the eggs to attach themselves to.

The fish clean the gravel with the caudal fin and tail until it is as bright as if every particle had been polished with a brush, often using the head and mouth to remove the larger stones from the nest. Some bass build several nests in a season and are compelled to remove a comparatively large quantity of rough and jagged material, yet very few wounded or abraded bass are captured. At Neosho the same bass have been observed at nest-building for seven years without showing a torn or worn caudal or anal fin. Trout, on the contrary, wear their caudal fins and tails to the very bone, in their efforts, and often die in consequence. In the Mississippi Valley, in Texas, and throughout the Southern States, the black bass deposit their eggs on the clay or mud, and rarely use gravel. At the Texas station, where gravel nests were placed in the ponds they were seldom or never used.

The proximity of the nests to each other depends on the size of the pond and the number of fish. They are sometimes less than 5 feet apart, and in a spawning pond of the Michigan Fish Commission, having only 108 square feet of surface and containing 30 adult fish, there were 8 nests. If the nests are near the banks, in water from 18 to 36 inches deep, the entire process of spawning and incubation is easily observed. The larger fish are apt to select deeper water, but they have been known to decline a clean lot of gravel, in water 3 feet deep and 8 feet away from the embankment of the pond, to build a nest on the naked clay bottom within reach of the bank, on which people were passing almost every hour. Nesting bass should have seclusion, although those reared in captivity probably fail to notice minor disturbances at the time of spawning which would at other times alarm them.

Shade is important, for, although bass sometimes build nests where there is no shade, in most instances they select places under overhanging grasses, lily-pads, stumps, and logs.

From the time the bass commence nest-building the attendant keeps

the pond and its contents under constant surveillance and maintains a close watch for fishhawks and herons. A record is kept, as nearly as practicable, of the date when each lot of eggs is laid, so that it may be known when to expect the young to hatch.

Artificial nests for bass have been used at one or two stations, as an experiment, but have been abandoned except for rock bass at Wytheville, Va. The nest is a wooden box about 20 inches square, with sides 2 inches high and slightly flaring outward. Cleats are nailed on the side for convenience in handling. Coarse gravel is placed in the bottom of the box and the remaining space is filled with fine gravel, flush with the top of the box. The top layer is sufficiently fine not to allow the eggs to fall through the spaces and mix with the large gravel underneath. The nest, thus completed, is placed in an excavation with the upper edge even with the bottom of the pond. A stake is driven near the nest and a board fastened to it, to afford seclusion and protection from the sun and enemies.

BROOD-FISH.

Whenever procurable, domesticated fish are to be preferred to wild fish for stocking the breeding-ponds, as they are less liable to injury in handling and transportation. A disrupted scale, lacerated fin, or a bruise on head or body frequently causes the death of wild bass, and their native surroundings are such that it is difficult to collect any considerable number of them. Moreover, adult fish captured from their native waters frequently fail to spawn in the year or season in which captured, on account of fright.

Bass not over 2 or 2½ pounds are recommended if the work is carried on in ponds which are to be frequently drawn off, but larger fish can be used advantageously if they are to be but rarely transferred to other ponds. Very large bass are more liable to injury when the ponds are drawn and the fish transferred, as they are more difficult to handle safely, and bruise and injure themselves in the tubs. Males and females should be in equal proportion, as an excess of males may prove a disturbing element at spawning time and later in the season may cause a loss by preying on the fry. The sexes of the black bass are not as easily distinguishable as of the trout. The number of adult fish for breeding-ponds depends upon the food supply. For several years past at Neosho an average of 30 breeding bass to the acre of water has been allowed, but that number might be increased.

SPAWNING HABITS.

When the nests are prepared and the spawning time arrives, the parent fish—especially the male—show considerable excitement and swim back and forth over and around the nest. In the act of spawning they cross the nest, their bellies close together, the male a little behind the female, and simultaneously void the eggs and eject the milt, the real act of spawning occupying a comparatively short time—

a minute or less. The eggs, when laid, are viscid, and as soon as voided and impregnated attach themselves to the floor of the nest. Then commences a parental watchfulness worthy of imitation on the part of some higher animals, one fish hovering immediately over the nest and maintaining a gentle motion of the fins for the purpose of keeping the eggs free from sediment, and the other acting as an outer sentinel, patrolling 8 or 10 feet away. Both male and female show great courage when guarding their eggs and young fry. A rock bass has been seen to leap entirely out of the water to bite viciously at an attendant's hand when moving aside the grasses sheltering the nest, and a black bass when guarding its nest has been known to attack and kill a snake three times its own length. The brightness of the nest makes the parent on guard easily distinguishable by enemies, like the fishhawk and eagle, but this danger may be materially lessened by planting the broader-leaf water-lilies near the nests, to afford shelter when in danger.

Black bass begin to spawn in the northern part of the United States about the middle of May, while farther south the season commences as early as March, and in all localities it is later in deep than in shallow waters. In the far South, in waters uniformly warm, the spawning time may not depend entirely on the seasons. The period lasts about two months. Many, if not all, discharge only a part of their eggs at one spawning. The maturation of the entire ovaries is never fully completed at one time, but the ripening is prolonged and the spawning done at intervals. As far north as southern Missouri and Illinois, black bass frequently spawn in the season following the spring when they are hatched, but this is not always the case; and farther north maturity comes later in life. Bass continue to yield eggs for a number of years, and some have been held in the brood ponds at Neosho which were adults when first taken to the station and continued productive for as much as seven years.

Rock bass have been known to produce two separate broods within one season as far north as southern Missouri, and this is probably true of some of the other basses. At Neosho they spawn when one year old.

EGGS AND FRY.

The eggs differ greatly in number and size, according to the age and size of the fish, varying generally from 2,000 to 10,000 per fish and from 80,000 to 100,000 per quart; 17,000 eggs have been found in a large-mouth black bass weighing 2½ pounds, a little less than 7,000 to the pound of fish; but on another occasion a careful count of the mature eggs showed only 2,674 to the pound of fish. Wide discrepancies in the figures may sometimes result from different methods of counting, as in rejecting or counting small eggs which are commencing their maturation for the next production. The rock-bass egg is fully three times as large as that of the black bass, and the fry are correspondingly large.

The varying factor of initial vitality and the impossibility of equalizing the intensity of sunlight render it impossible to determine pre-

cisely the period of incubation of any eggs treated in pond culture. With some kinds, under extreme temperatures and other less understood factors, wide variations are found. Bass eggs require from 7 days to 3 weeks for hatching, but usually from 8 to 10 days—depending mostly on the temperature of the water. Eggs artificially impregnated, in an experimental way, hatch in from 70 hours to 4 days at a temperature of 63° F., or somewhat over.

When the fry leave the eggs, they remain on the nest till the sac is absorbed, this depending, as with other fishes, on the period of incubation, modified by the temperature or condition of the atmosphere; usually a fifth less time being required to absorb the sac than for hatching the eggs. When the sac is absorbed, the fry rise and form a school which hovers over the nest usually from 2 to 4 days, settling back at night, except in extremely warm weather, when they may scatter in a few hours. A sudden fall of temperature may cause the school to settle back and remain a day or two longer on the nest. The tactics of the parents change and they no longer stand guard over the nest, but circle around the school, whipping back truants and driving off intruders. When the school rises and hunger begins to be felt, the fry separate and are driven for protection, by the parent fish, into shoal water or into the thick grasses; there they are deserted, and dispersing they seek the minute crustacea, larvæ, and insects. The brood bass should then be removed from the spawning-ponds to other ponds, or confined in compartments in the same pond, so that they can not prey on the fry.

For the first three to five days black-bass fry do not average one-fourth inch in length and are almost colorless, until the pigment forms along the back, making them appear quite dark when viewed from above, though it is difficult to distinguish the color of an individual fish when caught on a net of bolting-cloth.

Very young rock bass seem occasionally to attach themselves to the sides and bottom of the nests and to submerged plants. This action has not been noticed with black bass, possibly because their nests, being in deeper water, are more difficult of observation.

FOOD OF THE YOUNG.

Just how much food to give bass fry is as difficult to determine as with any other young fish. They are very greedy, and, if acceptable food is given them, appear to be hungry nearly all the time, and it is more than probable that the troubles caused by overfeeding other fishes would show themselves in the bass if they were overfed. Healthy fry have been carried at Neosho for four months with a loss of only 2 per cent. When first brought into nursery ponds or troughs they can not be induced to take prepared food, as they are wild and must be tamed or domesticated. They are fed almost every hour in the day, though but little food is given at one time and that is well scattered through the water. The attendant, without alarming them, should be about the trough constantly, to accustom them to his presence, and, instead of

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being frightened and darting into dark corners at his approach, they soon learn to come to meet him, not a few at a time, but all together.

For several days their food will have to consist of such minute animals as can be conveniently collected from the ponds with a dip-net of cheese-cloth. After four or five days they will accept prepared food, as fish of some kind, ground to a fine paste. In general, bass fry under 1½ inches in length are too small to take artificial food, and it is very doubtful whether it is good policy to transfer them to nursery ponds or troughs prior to that stage.

The number of young bass to be put into a pond depends upon its size and its capacity to produce food. If the nursery has been prepared in advance with aquatic plants some crustacea will be found there, and the deficiency is supplied by the introduction of snails, Gammarus, Corixa, etc. The use of beef liver as food is not advised. To a nursery in fair condition from 3,000 to 5,000 young bass may be allotted. The death of a part of these must be expected, and if even a fair percentage are to survive they must have much more food than the pond can probably grow. Should a large part of them survive the first few weeks they can be distributed into other nurseries.

At Neosho finely ground crawfish have been used for food with good results—not that crawfish have any value over other forms of aquatic life, but they are abundant, cost nothing, and are acceptable to the fish. Carp are cultivated for this purpose at the Fish Lakes in Washington, several hundred thousand being used each season, the young carp being liberated in spawning-ponds with the young bass a few days after they are hatched. At the Forest Ponds of the Missouri Fish Commission little branch chub are caught and placed in the pond several weeks before the bass spawn. As the chub spawn and hatch out before the bass, when the young bass are transferred to the nursery they find a lot of young chub ready to be eaten. An objection is that the old chub destroy the young bass, though this is easily obviated by hatching the chub artificially and turning only the young chub into the pond, or by removing the adult chub before the bass fry are introduced. At San Marcos the bass fry are fed on young carp, buffalo, and mud shad, in addition to the natural food, which is quite abundant early in the season, but later they take chopped fish, salted fish roe, etc. No effort is made to furnish the prepared food, though, until they reach 1½ inches in length, as they remain in the spawning-ponds until that time.

TRANSFER AND CARE OF FRY.

In transferring the fry to troughs or other ponds at Neosho two nets of cheese-cloth are required. The main one is about 30 inches square, supported by ribs from above; to the center of the ribs a handle is attached, so that the net can be used 5 or 6 feet from the shore; the net is made to sag to an open pocket in the center, which can be closed and tied with a drawstring. The second net is easily made from an

ordinary landing-net by replacing the netting with cheese-cloth. This will be useful in catching the fry that escape from the larger net. The transfer is made in tubs filled with water from the spawning-pond in order to preserve the same temperature as nearly as possible. Netting is done in the early morning, as the shallow waters of the pond become cool during the night and the temperatures of the different waters are more nearly equal. It requires patience and a degree of skill, which comes with practice. The operator stands on the bank and introduces the net with a gentle and scarcely perceptible side movement under the school and cautiously lifts it out, and when the net is clear of the water, turns with a quick motion and brings it over the tub, so that the part of the net holding water and fish can be readily submerged in the tub. An assistant stands near the tub to catch the sides of the net and help in the latter part of the operation. While the operator holds the rod to which the frame of the net is attached, the assistant slips his hands into the tub and unties the drawstring of the net pocket, and the net is then gently lifted out of the tub. A bucket of water from the pond and a dipper are kept at hand to wash into the tub any of the fry that may stick to the cheese-cloth. The fry should never be freed from the net with a feather or by shaking.

As soon as the collected fry are in the vessels they are carried to the troughs or pools, when the temperature of the water in the bucket or cans is compared with that flowing through the troughs. The experienced fish-culturist can tell by the touch whether there is a material difference in the temperature, and can take the steps toward equalizing it. Should there be a difference of 3° or more, it must be corrected. If a vessel is not crowded, an effective, but slow, method is to set or suspend the vessel in the water flowing through the pool or trough. If the water in the vessel is warm and the time short, in addition to setting the vessel in the trough, a part of the water may be bailed from the vessel and replaced with fresh colder water. This operation is called "tempering"; it requires care, good judgment, and patience.

It is well to have several large buckets made with "windows," that is, a small screen of perforated metal in one side of the bucket, near the top. This bucket is put in a trough under a small jet of water, conducted by a rubber tube to the bottom of the bucket. The jet discharging at the bottom of the bucket, and the surplus water escaping through the perforated window, assist in equalizing the temperature, and the fish are then carefully put into the troughs or pools.

A part of the fry do not find their way through the wire screens into the cut-off, and all around the margin of the pond, even in the deep water, straggling fry may be seen. Sometimes these scattered youngsters are small, but generally they are the largest. After all the fry have been captured from the cut-off and the season's spawning is over, the pond is drawn to collect and save those that have failed to come into the cut-off. This work is generally in June or July, when the

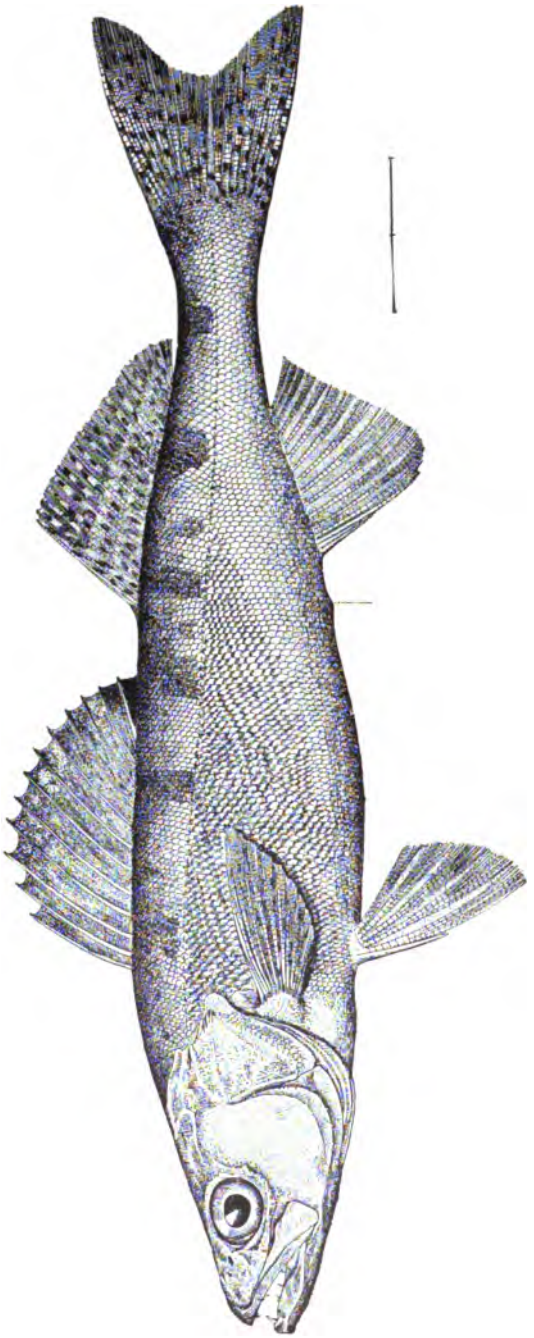
ponds are quite warm and the temperature of the atmosphere is high, and is carried out with extreme watchfulness and care, as the midsummer drawing of a bass pond is the most delicate operation connected with the propagation of this species in ponds. These fry need to be "tempered" and sorted in the same way as advised for other fry.

At some stations of the Commission the fry are not transferred from the spawning to the nursery ponds until they are 1½ inches long. In effecting the transfer a seine made of wash-netting or bobinet is used, the length and depth of the net depending on the size of the ponds. The fishing is usually done early in the morning, near the inlet where the young fish collect. The fish are transferred from seines to tubs by dip-nets, and thence to the tanks, where they are carefully assorted and placed in the nursery ponds. Sometimes they are assorted in the tubs and put at once in the ponds.

As the season advances it will be noticed that some of the fish grow much more rapidly than others, and as this is generally the result of cannibalism, the larger ones preying on the smaller, the fish must be again sorted and those of different ages placed in separate ponds. The successful raising of bass in ponds depends largely on frequent and careful sorting.

Collecting for shipment occurs in the cool days of autumn, as experience has shown that the bass can be much better and more safely transported in the spring and fall than in the summer. They can be transported more cheaply in midwinter than any other time, but when fish are moved long distances in very cold weather (or at any other time when much ice is used in the cans) many die from gill troubles. After the ponds are free from vegetation and are ready for drawing off, the water level is reduced slowly. Every precaution is taken not to frighten the fish, and with this in view no more attendants are allowed about the bank than are absolutely necessary. Black bass when frightened will burrow in the mud and live there an incredible length of time, and if a fingerling burrow in the mud when the pond is being drawn he may prove a dangerous occupant the following spring when the young fry are introduced. The same precautions should be observed in transferring fingerlings as with the very young fry.

During the various stages of its life the bass is subject to the attack of enemies of many kinds. The fish-eating birds, like the kingfisher; wading birds, like the heron, and amphibious animals, like the mink and muskrat, must be guarded against. Snakes, frogs, turtles, and various beetles are dangerous to the fry, and sometimes even to adult fish.



STIZOSTEDION VITREUM. *Pike Perch or Wall-eyed Pike.*

THE PIKE PERCH OR WALL-EYED PIKE.

DESCRIPTION OF THE SPECIES.

The pike perch (*Stizostedion vitreum*) is the largest member of the perch family inhabiting American waters. The body is fusiform; its depth being contained about 4½ times in length. The head is long, pointed, and a little more than one-fourth the body length. The large mouth is provided with bands of villiform teeth, in addition to which there are long, formidable canine teeth on the jaws and roof of mouth. The eye is contained 4½ to 5 times in head. Serrations exist on the preopercular bone, and several spines on the preopercle. The high dorsal fins are well separated, and contain from 12 to 16 spines and 19 to 21 soft rays. The number of rows of scales in a lateral series is from 110 to 132, with about 10 rows above and 25 rows below the lateral line. The general body color varies from light yellowish to dark blue, with indistinct lines and mottlings, the under parts being white or pink. A large black spot involves the membrane of the last two or three dorsal spines, the fin being otherwise nearly plain; the second dorsal and the caudal are mottled with yellow and olive; the pectoral is dusky at its base, and the anal and ventrals are pinkish.

Three rather well-defined color varieties of the pike perch may be recognized, dependent on age and environmental conditions. These are the gray, yellow, and blue. The gray variety attains the largest size, 40 pounds being the maximum and 10 to 20 pounds being common. The yellow form reaches a weight of 20 pounds, and is often taken weighing 5 to 10 pounds. It has the widest range and is the most numerous. The blue pike occasionally may reach a weight of 5 pounds, but averages under 1 pound. The gray and yellow varieties are usually found in the larger streams, and in the Great Lakes seek water 10 to 40 feet deep, while the blue variety seems to prefer water 30 to 75 feet deep.

The pike perch in that part of Lake Erie adjacent to the islands of the western end are almost or entirely free from yellow, being a dark gray, almost black, on the back, shading on the sides to lighter grays, while the lower third and belly are silvery white; the body is less compressed and tapers less toward the tail than the yellow variety. In Sandusky Bay there is a uniformly yellow variety, of a fusiform shape. Although Sandusky is connected with the lake by a deep channel over a mile wide, it is reported that the yellow fish do not leave the bay and the gray fish rarely enter except during the spring, when small numbers resort to it to spawn.

From the sauger or sand pike (*S. canadense*), the wall-eyed pike is distinguished by its fewer pyloric cœca (3 instead of 5 to 7), fewer dorsal

rays, larger size, presence of black blotch on second dorsal, absence of similar blotch at base of pectorals, and some minor characters.

Various names are given to the pike perch in different parts of its habitat, and two or more names in some localities. Wall-eyed pike is the most widely used designation. Pike and pickerel are employed in the Great Lakes. As both of these names are also borne by the members of the genus *Lucius*, much confusion has arisen. In the Susquehanna and Delaware rivers and along the Ohio and its tributaries the fish is very inappropriately known as salmon. Dory or doré is a Canadian designation. Other names in use on the Great Lakes and elsewhere are yellow pike, blue pike, glass-eye, white-eye, and jack salmon. In order to avoid confusion and to indicate the family relationship, the U. S. Fish Commission has recommended the name pike perch, the fish being a perch of pike-like appearance and habits. This name corresponds with the generic term *Lucioperca*, applied to a similar European species. The sauger, however, is entitled to bear the same name, although its usual designation is distinctive.

GEOGRAPHICAL DISTRIBUTION.

The pike perch prefers clear water, with rock, gravel, sand, or hard-clay bottom. The center of its abundance is Lake Erie, but it is among the most widely distributed of our fresh-water fishes, its range extending along the Atlantic seaboard from New Brunswick, New Hampshire, Massachusetts, and Connecticut as far south as North Carolina; thence to the northern portions of Alabama, Georgia, Mississippi, and Arkansas on the south, with Kansas, Nebraska, the Dakotas, and Assiniboia its western limit and the Hudson Bay system its northern boundary. Over the greater part of this vast area it is fairly abundant, and in all of the waters of the Great Lakes region, the Mississippi basin, and the southern portion, at least, of the Hudson Bay system it is commercially important. In New Hampshire, Connecticut, New Jersey, and eastern Pennsylvania it is not indigenous. Its adaptability to suitable new waters is shown by its acclimatization in the Susquehanna and Delaware in Pennsylvania, in many small lakes in Michigan, and in the streams and lakes of Nebraska, where it has rapidly multiplied and is a great favorite with anglers and epicures.

The range of the sauger is less extensive than that of the wall-eyed pike. It embraces the Great Lakes region, west to the Upper Missouri, and south to Arkansas and Tennessee.

ECONOMIC VALUE, FOOD AND GAME QUALITIES.

The pike perch is one of the most valuable fresh-water fishes. In Lake Erie alone the annual catch is now upward of 6,000,000 pounds, valued at $225,000, besides which over 3,000,000 pounds of saugers, worth $75,000, are yearly taken in the same waters. Throughout its range it is caught nearly the year round, and, in spite of the zeal with which it is pursued on account of its fine table qualities and the ease

with which it is captured, it is holding its own well owing to its hardiness, its comparative freedom from disease, and the facility with which it is produced by fish-cultural methods.

As a table article it ranks high. The smaller fish are delicious fried, broiled, or boiled, while the larger ones, weighing from 5 to 15 pounds, are excellent when baked. The flesh is firm and well flavored, even in the warmest weather. Few fish stand shipment, holding, or freezing better than pike perch. It is not so well adapted to salting as some species, but this is not important, as the demand for it is so great that the supply is always disposed of fresh or frozen. The abdominal cavity is comparatively small and the head medium, so that little loss occurs in dressing. The bones are somewhat numerous, but they are generally large and easily separated. The gray and yellow varieties are considered superior to the blue for food, and are also better game fish.

The pike perch, although capricious, is readily caught with baited hook, artificial fly, spoon, etc., and deserves high rank as a game fish. About 100 tons are taken annually with hook and line through the ice about the Bass Islands, Lake Erie; large quantities are also thus caught near Buffalo, N. Y., in Saginaw Bay, Mich., and elsewhere. In ice fishing small minnows are generally used, the bait being taken near the bottom.

FEEDING HABITS.

Although the pike perch is predaceous, observations would seem to show that it devours fewer desirable species than any other predatory fish. Its main food in Lake Erie the year round is a small cyprinoid, usually called lake shiner, which abounds in these waters, with occasionally crawfish in the winter and the larvæ of insects and the insects themselves in the warmer months. A pike perch weighing 16½ pounds has been caught containing a bullhead which in its partly digested condition weighed 9 ounces. The stomachs of hundreds have been opened at all seasons of the year and under various conditions, and the examinations have as yet failed to disclose one containing a whitefish, black bass, or other valuable fish. Usually the stomach was empty so far as the unassisted eye could discover, except for a thick, tough, greenish-yellow slime.

The pike perch does not generally inhabit the depths of waters frequented by the black bass, preferring the deeper portions of the shallow parts of the lake. Excepting the blue pike variety, it is not found in deep water, which is the home of the whitefish during all the year except for a short period in the fall during its reproductive migrations. And even the blue pike does not inhabit the deep waters where the whitefish and cisco spend most of their lives.

SPAWNING AND SPAWN-TAKING.

The pike perch is not a nest-builder, as are the basses and sunfishes. The female discharges her spawn in shoal waters, the male following and emitting milt in proximity to the eggs. The spawning time varies

greatly in different localities, extending from the last of March with the yellow and gray varieties to the latter part of May. The blue pike has not been hatched by fish-culturists, and comparatively little is known of its spawning habits.

The work of collecting eggs for artificial propagation generally begins about the 10th of April and extends to the 25th of that month. The eggs are obtained from fish taken by commercial fishermen. Half or more of these are hatched into vigorous fry and deposited in public waters, and but for this work all the eggs thus saved would go to the market in the abdomens of the fish and be entirely lost.

The pike perch develops a greater number of eggs in proportion to its weight than the whitefish, and but a small percentage of them are fertilized under natural conditions. The eggs are 0.08 inch in diameter and average about 150,000 to a fluid quart. About 90,000 eggs would probably be a fair average per fish for Lake Erie, and as the spawning fish will average about 2 pounds each, 45,000 eggs to the pound weight of fish would approximate the true figures.

As the spawning time approaches spawn-takers are stationed at the various points on the lake where nets are to be fished. A spawn-taker accompanies the fisherman on his trips to the nets and examines the catch for ripe fish. His equipment is the same as that described in the chapter on whitefish, except that he takes a quantity of swamp muck for use in preventing adhesion of the eggs. After he has selected and stripped a fish, it is returned to the fisherman. The eggs after being fertilized are either shipped directly to the hatchery or through some central collecting station.

The inner membranes of the egg are delicate and easily ruptured, and the greatest care is necessary, from the taking of the spawn to the hatching of the fry, and especially until they are cushioned by the filling of the membranes with water.

The fish should be wiped so that slime will not drip into the spawning pan, as a very small portion will clog the micropile and prevent impregnation. The female is grasped firmly in the left hand just forward of the tail, with the back of the hand downward, the fingers outward and the thumb above and pointing upward, the head of the fish being held between the spawn-taker's right wrist and body, the right hand grasping the fish from below, just back of the pectoral fins, the fingers inward, the thumb outward. The anterior portion of the abdomen is thus firmly grasped and the pressure brought to bear on the eggs in the ovaries of the fish. A woolen mitten on the left hand allows a firmer grasp on the slippery body than is possible with the bare hand. The fish is now at an angle of 45°, the body forming a modified crescent, with the vent within 2 or 3 inches of the bottom of the pan. This position throws the pressure on the abdomen and facilitates the opening of the vent and the flow of the eggs. Gentle pressure is now maintained as long as the eggs come freely and in a

fluid stream, probably over half of them being procured before the hand is moved, but when the flow slackens, and not until then, the hand should be moved slowly toward the vent without releasing the pressure and only fast enough to keep the eggs flowing in a continuous stream. When this stops the hand should be replaced and the process repeated until all the good eggs are procured. If the eggs do not start readily they should not be taken.

As soon as one female is stripped the milt is added, care being taken all the time to allow no water in the pan until the lot is finished or until the pan is half or two-thirds full of eggs. If males are abundant one is stripped for each female, and one for every two or three females in any event. When the pan is about half full, and before any water is added, the eggs are very thoroughly and carefully stirred with the outstretched, spread fingers, and enough water is added to incorporate the egg mass and nicely cover the eggs, the whole being mixed again with the fingers and allowed to stand for 2 minutes. Next the milt of one or two more males and a little water are added, the mixture is stirred as before, and again allowed to stand for 5 minutes.

Impregnation can not take place unless the milt and eggs come into perfect contact, and as the milt dies 2 minutes after water is added, and as the eggs will not become impregnated after having been in water 6 minutes, it can readily be seen that the eggs and milt must be thoroughly and quickly mixed, both before and after the water is added. A tablespoonful of muck solution is now stirred into the mass and a pint of water added. The water is poured off after standing and this process is repeated every half hour, as described on pp. 174–175.

After the adhesion has subsided the eggs are placed in a keg nearly filled with water and stirred every half hour, with a change of water at least every hour from the time the eggs are taken until they are delivered at the station. The stirring is thoroughly, but gently, done with a dipper, care being taken that the dipper does not strike the sides or bottom of the keg.

The eggs should never be exposed to the sun, and the water surrounding newly taken eggs should preferably be kept between 40° and 50° F.; in fact, experience has shown that even 35° is not harmful. Of course, all sudden changes of temperature should be avoided.

DEVELOPMENT AND CARE OF EGGS.

When the eggs arrive at the station they are held in 15-gallon cans for about 24 hours, a gentle stream flowing into each can, this being considered better than to place them at once in the hatching-jars, where the motion is too violent for the green eggs. While thus held they are stirred every hour. Kegs or cans may be carried half full of eggs if properly cared for.

For the handling of all eggs at Put-in Bay, except those to be shipped by rail or wagon, 15-gallon pine kegs, painted outside, with iron hoops and iron drop-handles, are preferred to tin cans. They are cheaper,

lighter, more durable and convenient. The eggs are in full view when being stirred and when water is poured off or added; the most important point, however, is that the kegs retain the water at a more even temperature, as they are less affected by heat and cold than the cans. All dishes and implements with which the eggs come in contact should be thoroughly scalded and cleaned at the beginning and close of each egg-taking season.

For hatching pike-perch eggs at Put-in Bay the same jars are used as for the whitefish eggs, and on pp. 115–119 will be found a description of the hatchery and its equipment, the arrangement of the jars in a "battery," the manner of operating them, etc. The pike-perch eggs are lighter than many others, and, being hatched in comparatively warm water, fungus quickly when dead. The water used in hatching them should therefore be practically clear, for if it contains any considerable portion of silt the fungused eggs will soon become so loaded as to possess the same specific gravity as the living ones, and sink in the egg mass, forming lumps which can be removed only by screening, which is always more or less injurious. Even the live eggs will become coated, interfering with the proper working of the jars. Where clear water is used the fungused eggs remain buoyant, keep on top of the egg mass, and are easily removed without loss or injury to the live ones.

Where water is only moderately turbid and a large number of eggs are being handled, if the water temperature runs up to 55° or 60° the eggs will fungus so rapidly that they can not be separated fast enough to prevent the live eggs from becoming mixed with them. As it is practically impossible to run "hospital jars" under such conditions, many eggs must be lost, or the small percentage of live ones contained in the mass of dead ones must be drawn off and distributed in the lake and thus given a chance there to hatch. Both of these conditions are to be deprecated and can be prevented by a filtering plant.

In order to insure perfect cleanliness, it is advisable to treat the whole system of troughs and pipes through which the water runs, once or twice a year, with a clear solution of chloride of lime, beginning with the supply tanks, which should be thoroughly washed inside, and following down until all have been reached, opening each faucet or cock during the procedure. In this way, at small expense, the system is freed from infusoria and other forms, which at times are very troublesome and more or less destructive to the eggs. This work should be done in the fall, just before whitefish eggs are to be placed in the jars, and again in the spring, as soon as the whitefish eggs and fry are all disposed of and before the pike-perch eggs are received. If these periods overlap, a battery at a time can be treated. After treatment, the tanks are thoroughly washed and the whole system is flushed for an hour or more. Chloride of lime is much more effective for this purpose than common lime. The preparation is made by dissolving 5 pounds of chloride of lime in 10 gallons of water, and after it has settled the clear solution is decanted off and added to many times its bulk.

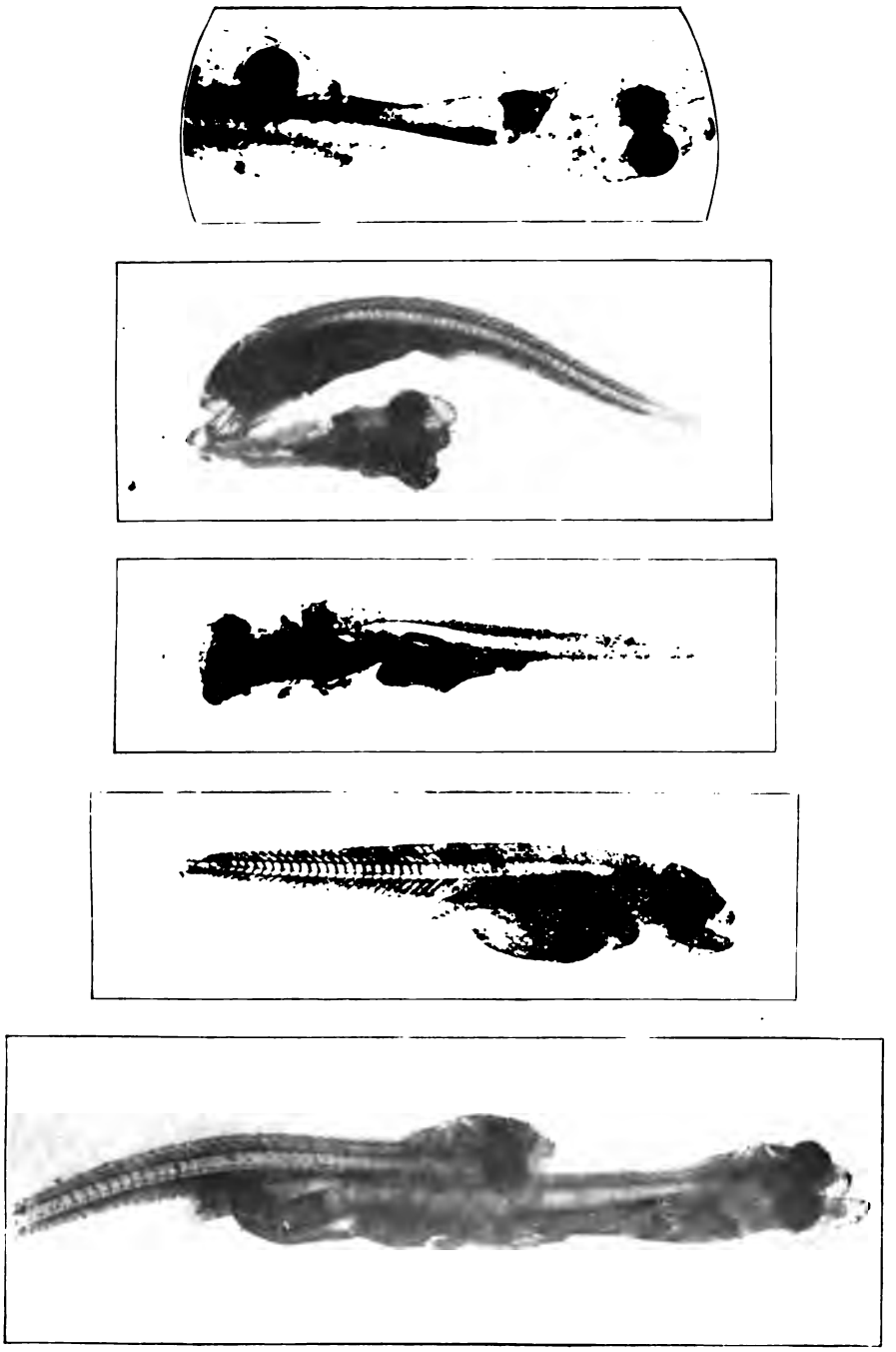


PHOTO-MICROGRAPHS SHOWING PHASES OF CANNIBALISM AMONG PIKE-PERCH FRY.

The fry of the pike-perch are only about as large round as ordinary sewing thread and about $\frac{3}{16}$ inch long; it therefore requires very fine brass-wire-cloth screens to hold them in the tanks, and it is exceedingly important that these screens be kept clear—preferably by the air jets described in the chapter on whitefish (p. 119). This apparatus gives perfect satisfaction and twice the number of whitefish or pike-perch fry can be successfully carried in a given amount of water with the air system than without its aid.

When the eggs are placed in the jars 24 hours after taking, allowance is made for some additional swelling, and accordingly $3\frac{1}{2}$ quarts of eggs are placed in each jar on setting them up. These will swell to 4 or $4\frac{1}{4}$ quarts at the end of 3 days, and that number works best. The eggs are worked with the least possible amount of water that will keep them in motion throughout, and anything beyond this is harmful and will result in ruptured yolks. The jars are inspected daily, and one that is working too fast or is not working uniformly is carefully adjusted.

The eggs are semibuoyant and very adhesive. A single large, spherical oil-drop floats at the top of the yolk mass. The germinal disk is on the side of the yolk. The first cleavage of the disk ordinarily takes place in 5 to 6 hours in a water temperature of 45° to 50° F. Unequal division of the disk is rare, although it sometimes occurs, while with the whitefish and many other species inequality of cleavage is the almost universal rule.

In a water temperature of 45° to 50° the form of the embryo may be distinguished under a low-power glass in 4 days, and the eye-specks can be seen by the unassisted eye in about 6 days. By this time the pigment cells, or color stars, can also be seen with a microscope of moderate power, as well as the pulsations of the heart and the coursing of the blood through the vessels—the red corpuscles being distinguishable.

At this stage any monstrosities, malformations, and other blemishes may be easily discovered. They consist of embryos with double heads, the most common form, more than the normal number of eyes, curved spines, and various other deformities, some so slight as to be scarcely discernible. All these erratic forms perish before hatching or soon afterwards, and cause the loss of a large percentage of the eyed eggs, which die before hatching; insufficient food supply in the yolk causes the loss of the next greatest number, the two covering about 60 per cent of the whole loss of eyed eggs.

The eggs hatch in from 7 to 28 days, a mean temperature of about 57° producing the first result and about 40° the latter, neither extreme furnishing the best of fry. At a temperature of about 48° the eggs will hatch in 18 to 20 days and produce vigorous, healthy fry.

The absorption of the food-sac is governed by the period of incubation and in some measure by the water temperature, and a day or two after its complete absorption cannibalism will begin. If 28 days have been required the sac will be absorbed in from 5 to 6 days, while if a

shorter period—say of 14 days—has been required, it will likely take 10 days before the sac is fully absorbed and the fry begin to destroy each other.

TRANSPORTATION OF EGGS.

The best method of shipping eggs a considerable distance before hatching is a somewhat open question. The experiment of shipping them on trays rather than in water in kegs or cans, as described above, has been tried with varying success. If shipped on trays they should be accompanied by a watchful messenger, who will see that they are not subjected to sudden jars while in transit. They should be spread on the trays not over one-third of an inch deep, and should be sprinkled lightly every day. The cases containing the eggs should be packed in damp sawdust, so that all parts of them will be covered 6 or more inches. Ice should be used if the air temperature is higher than 45° or 50° F., as the nearer the eggs can be kept to 40° F. the better.

Eggs held from 2 to 5 days on trays at Toledo and then shipped 40 miles by steamer to Put-in Bay came out as well as the average of the eggs received near home and held in running water 24 hours. A lot shipped on trays from Put-in Bay to Cape Vincent, N. Y., about 400 miles, came out badly, while those from the same lot carried in water turned out well. This difference is probably accounted for from the fact that the eggs carried in water were not subjected to sudden jars, while in the other case they doubtless were. It is quite possible that failures in shipping pike-perch eggs on trays have been largely owing to concussions received during transit, such as must result in carrying them on railroad cars and wagons.

If the eggs are to be transported long distances, they should be covered with cheese or mosquito cloth and the remaining space to the top of the tray filled with damp sphagnum moss; but if only a distance of 75 miles or less is to be traversed, this is unnecessary, care being taken to keep the cases right side up.

Eggs that have been held on trays should be placed in running water, in kegs or cans, a few hours before they are put in the jars, or an allowance of about 12 per cent should be made for shrinkage of the eggs while on the trays. Otherwise too many eggs will be put into the jars to work well.

PLANTING THE FRY.

In order to prevent loss from the fry preying upon each other, whenever practicable they should be planted before the sac is fully absorbed, but not for 3 or 4 days after hatching, since if they are so held they gain strength, and if they are to be transported some distance, they become better fitted for withstanding the hardships of a long journey. But with large numbers, running into hundreds of millions, lack of space makes it necessary to liberate them almost as fast as hatched. Darkening the tanks prevents cannibalism, but owing to the absence of food and possibly to the darkness the fry become weak and light-colored in

a day or two and will not stand transportation. They must, therefore, be transported before the sac is fully absorbed or large numbers will be lost by either cannibalism or starvation.

During the season of 1899 the water pumped from the lake for the supply of the fry tanks at the Put-in Bay Station literally teemed with crustacea, such as *Cyclops*, *Diaptomus*, *Daphnia*, *Alonopsis*, etc., but at first, after the food-sac was absorbed, the fry refused to partake of these, their supposed natural food, and preyed on each other instead. Three or four days later, however, a few hundred fry held for experimental purposes devoured these crustacea greedily and throve upon them as long as the supply was kept up. When cannibalism was at its height 50 fry were placed in a tin pan, with myriads of crustacea. In 10 minutes there were 6 cases of cannibalism. In each case one of the fry seized the tail of another and swallowed all it could. Close watching failed to discover any of these fry attempting to seize one of the crustacea. It was also discovered that neither the fry of the whitefish nor of the pike perch, when later they began to feed on the crustacea, would touch a *Diaptomus*, although the most showy of all the *Entomostraca* present and resembling very strongly the *Cyclops*, with which it is closely related. When a hungry fry would, as if by accident, seize a *Diaptomus* it would at once reject it and go about showing unmistakable signs of discomfort. Contrary to the general belief, the fry do not always die from the effects of eating other fry. The swallowed portion may be digested and the head and attached tissues finally rejected.

It has been customary to employ the same method in planting pike-perch fry as in planting whitefish fry; that is, the fry are dipped from the fry tanks of the hatching battery into cans or kegs and transported on a steamer to the points selected, where the cans are carefully lowered into the water and the young fish allowed to swim out.

Toward the close of the season of 1899 an experiment was made of carrying fry to the planting-grounds in a tank on board the steamer. The tank held 400 gallons, and was therefore equal in capacity to forty 10-gallon cans, but it was found in practice that a half more fry could be carried in this way with a given amount of water than in cans, as there was a continual stream going in through hose connected with a deck pump and out through screened siphons, whereas with cans some must stand while the water in others is being changed. Moreover, it is impossible to get a maximum number of fry in each can, so that some cans are carried with fewer fry than they should contain, while experience soon taught how many could be safely handled in the tank.

The fry were drawn from the fry tanks in the house direct to the tank on the steamer through a 1-inch rubber hose, acting as a siphon, the suction end being held near the air supply, where fry collect in largest numbers. This required 10 to 15 minutes, while by the old method of dipping the fry into tubs and then distributing them into the kegs on board it would take more than an hour. This saving of time is very

important when fry are hatching rapidly. Another advantage is that by passing the hose about close to the bottom of the tank nearly all the shells are removed with the fry, thus keeping the tanks comparatively clean. Examinations showed that the fry were not injured by passing through the hose, which is also an advantage over dipping them out with scoops.

On arriving at the field of planting, the fry and water are discharged through a section of hose about 10 feet long, leading from the bottom of the tank. The steamer is kept at a slow speed at the time and the transfer of the fry to the water is accomplished as gently at least as would be the case in emptying them from kegs. Considerable time, as well as much hard work, is saved by this plan, and so far there appears to be no objectionable features in it.

USE OF SWAMP MUCK TO PREVENT ADHESION OF EGGS.

Many experiments have been made from time to time to determine the best means to prevent adhesion in the pike-perch eggs. This may be accomplished by constantly stirring the eggs from the time the water is added until it fills the egg and adhesion ceases; but this causes loss of time and a large percentage of yolks will inevitably be ruptured. Another method is to allow the eggs to agglutinate into a mass and stand thus until fully hardened, afterwards separating them by gently rubbing them between the hands, but this also sacrifices time. The date of the first use of foreign, inert substances to prevent adhesion is uncertain. Fine clay dust and clay in solution have been used with success and experiments with starch have given good results. By a series of experiments with eggs taken in the vicinity of the station from the boats of the fishermen, and from the penned fish as well, it was found that the proper use of swamp muck obviates the difficulty, with a great saving of time, labor, and eggs.

In the spring of 1895 finely divided, washed, and screened swamp muck was tried at Put-in Bay and has been used ever since, and recently with complete success, owing to a change in the method of application. The plan pursued up to 1899 was to add muck to the water in the kegs into which the eggs were poured after impregnation and to wash them quickly. The washing was done quickly in order to prevent adhesion. This was effective, but it involved the use of too much muck, which was removed from the water with some difficulty, and which smothered the eggs if left in too long in any quantity, and, furthermore, it was difficult to get exactly the right quantity of the mixture. Careful experiments were therefore made in using the muck in the pan immediately after impregnation had taken place and satisfactory results were obtained. The eggs are allowed to stand in the milt for about 10 minutes with sufficient water to barely cover them, being carefully stirred once or twice meanwhile. Then a tablespoonful of the muck mixture, of the consistency of thick cream, is added. Next the pan is nearly filled with water and stirred thoroughly, when

it is left half an hour, or while another pan is being filled. Without moving pan No. 1 more than is necessary the surplus water is poured off, the pan again filled, stirred, and left as before, while pan No. 2 is treated like the first. If the boat rocks so as to endanger the safety of the eggs it is better to pour them carefully into the keg and let them stand there, keeping only about an inch of water over them and pouring the water off and adding fresh water at intervals of not more than half an hour.

The important point in preventing adhesion is to leave the eggs alone until the particles of muck, or the spermatozoa, in case the eggs are held in the milt without the addition of muck, have settled, and then pour off the comparatively clear water, adding a fresh supply and then gently agitating the eggs. It will be observed that most of the muck particles will have settled in one minute, the water becoming measurably clear. If the eggs are held in the milt, the water being very milky from the mixture, the water will become comparatively clear in 3 or 4 minutes. This is because the spermatozoa are slightly heavier than the water and settle to the bottom. In either case it is important to retain the particles in the remaining water and eggs until adhesion has ceased, in order to keep the eggs separated from each other, for although the particles of muck or the spermatozoa, as the case may be, are adherent, sticking to the surface of the egg, they are easily washed off, thus permitting the eggs to come into contact and become fastened together. Aside from the washing off, the area of the egg membrane becomes constantly greater, removing the particles farther and farther from each other until finally the surfaces meet and adhesion takes place. This will not occur if the muck particles or the milt are left in the egg mass until adhesion has ceased or until the egg has become practically filled with water—that is, has finished swelling.

The first great loss of eggs is owing to lack of impregnation, and the second, shown by their turning white, is owing to the rupture of the sac. While the eggs are soft and not cushioned by the absorption of water, the greatest care possible will not prevent the rupture of a considerable percentage of the sacs where the old method is pursued of constant working to prevent adhesion. By holding the eggs in the milt—which is better than the old way and requires less labor, but is not to be compared with the muck process—or by using muck, with reasonable care in all other directions, the loss is very slight, as has been shown by careful experiments and counts.

Muck has proved far superior to starch or any other substance which has been tried at the Put-in Bay Station, starch being prone to settle into a hard mass among the eggs, requiring considerable work to again dissolve it, with more or less injury to the eggs.

The preparation of the muck solution is very simple, but should be carefully conducted, as follows:

At a suitable place in a swamp a depression is dug, which quickly fills with water. Muck is now suspended in this water by thorough

beating and stirring until most of the muck particles are freely divided. Care is taken not to get the mixture too thick, as the sand will not settle out nor can the mixture be screened freely. This is poured through a screen placed across a washtub until the tub is full, when the débris is knocked off the top of the screen and another tub is filled. The partially clear water is poured off of tub No. 1, it is again filled with muck, and this is continued until there are a few quarts of muck of the consistency of cream in the bottom of the tubs. The tubs are next filled with water, which is agitated thoroughly, and then allowed to stand a few seconds to give the particles of sand time to settle. The contents of the tubs are then emptied into kegs or cans, when the water may be poured off in an hour or more. This leaves quite a thick mixture of even consistency, as shown under the microscope. It should be free from sand, which would collect in patches in the bottom of the jars and interfere with the working of the eggs.

It is very necessary that the muck be now thoroughly cooked or scalded, otherwise infusoria will develop on the eggs, causing much inconvenience and some loss. Finally the muck is drained off, dried in any desired form, and held ready for use. It should be prepared before the egg-collecting season begins. The screen is about 20 inches by 30 inches and is made by tacking to a wooden frame a fine wire cloth of 40 meshes to an inch. The finest mesh that will let small particles of muck through is best. The cloth is bagged down somewhat, with the tack heads up, in order to present a smoother surface for the quick cleaning of the screen.

PENNING FISH.

The plan of holding in pens adult fish taken prior to the spawning season has been tried with pike perch as well as with whitefish. This is done to insure a sufficient and definite number of spawners, the collection of which during the spawning season is sometimes interfered with by stormy weather or other causes. Contrary to what would be naturally expected, the pike perch is much more difficult to handle in this way than the whitefish, probably owing to the higher temperature of the water at the time the work is carried on. Fewer can be transported in the tanks on board of steamers and fewer can be held in the pens. Where injuries have occurred fungus is apt to set in much earlier than with the whitefish, and on this account excessive care is necessary in handling pike perch, as well as to prevent injury to eggs in the ovaries. While the male whitefish can be held and used over for two or three days, the pike perch can be used but once, and when held for several days, especially late in the season, the milt comes from the fish thickened as if taken from a dead fish, and is far from being at its best. However, this is true to a great extent with the fish taken fresh from the nets late in the season. Females which do not "ripen" within two or three days are likely not to furnish eggs at all, and if held even two or three days late in the season are likely to yield eggs which will not hatch.

Pike perch are obtained in the same manner as the whitefish, from the pound nets of the fishermen. They are sometimes taken directly into the tanks on board the steamer from the pound when it is raised, but more often are dipped into supplemental nets by an employee of the Commission, who accompanies the fishermen when the pound is lifted, and are held until they can be picked up at leisure by the steamer. This permits the gathering of fish from many nets, while if they were taken directly from the pound only one lifting boat can be followed at a time and comparatively few fish collected. The supplemental nets are placed at each pound net where fish are expected. They are 3 feet in diameter and 7 feet in depth, and are held open at top and bottom by rings of half-inch iron, the bottoms being provided with puckering-strings to close them. The top ring is fastened to the outhaul stake and rim line of the pound, the lower one hanging free and acting as a weight to hold the end in place, and also serving to keep the net open so that the fish will have plenty of room and not be scaled by chafing against the meshes. When thus located, the supplemental net is in a convenient position for receiving the fish when the pound is lifted. Rowboats transfer the fish in tubs to the steamer, where they are placed in tanks and transported to the pens, where they are counted and assorted according to their ripeness.

The pens or live-boxes used in the pike-perch work are the same as those used for whitefish. Stationary live-boxes, supported by piling, have been used, but as the water at Put-in Bay becomes too warm for this, the boxes are now made so that they can be towed, like a raft, into open waters where the current is more vigorous and the temperature more uniform. Another advantage gained by this method is that an equal depth of water is maintained in the live-boxes, the rise and fall in this section varying from 4 to 5 feet in a single day, according to the direction and velocity of the wind and the atmospheric pressure. The boxes are 16 feet long, 8 feet wide, and 8 feet deep, divided into two equal compartments 8 feet square, provided with false bottoms controlled by standards running in guides at the ends. The standards are pierced by inch holes at intervals of 6 inches, so that the false bottoms may be held at any desired place.

The pens, in groups of five, are fastened end on between booms, and the whole thus forms a raft. The booms are made of 4 by 8 hemlock joists, 2 feet apart on the outside, trussed at frequent intervals by diagonal cross braces and ties, on top of which are placed two tiers of 1-foot wide hemlock planks, thus making the booms when completed 52 feet long, 2 feet wide, and 1 foot deep, and quite strong and rigid, capable of withstanding seas of considerable violence. At each end and between all the crates are placed 2-foot plank walks, giving ample room for working on all sides, which is a great convenience in handling fish and procuring eggs, especially in stormy weather. The pens are now made of boards 3 inches wide, nailed 1¼ inches apart, which gives sufficient space for free circulation of water. The lumber is dressed

on all sides and all inside corners are rounded, as the fish injure their noses on square corners in their attempts to escape. All parts of the pens are interchangeable and easily taken down for storage, being held in place by 4-inch log bolts. The pens are fastened to the booms by log bolts 6 inches long.

Much depends on the work of transporting either whitefish or pike perch from the nets to the pens, not only in moving the fish with the least possible injury, but in the saving of time, so that greater numbers may be penned and the risk of holding the fish in the supplemental nets may be minimized. Tow cars have been used, but they retard the speed of the steamer fully one-half, and tanks on the decks of the steamers have therefore been adopted. It is better to have several smaller tanks than one large one, as the fish can be dipped more readily from the small tanks and the water is not so violently agitated during rough weather. A convenient size is about 6 feet long, 4 feet wide, and 3 feet deep. The tank has two lids, submerged about an inch, arranged to open crosswise of the center and held by lugs below and by pins above. The lids are made of 3-inch boards nailed firmly upon cleats on the upper side, with about ¼-inch space intervening. This prevents slopping in any weather when fish should be handled. The tank is smooth and it has no obstructions inside. A 2-inch hole at the bottom at one end is provided for drawing off water, and one of the same size within 3 inches of the top for an overflow, when fresh water is being added. Fresh water must be furnished, varying as to the number of fish. This can be supplied with a "donkey-pump," the hose being carried from one tank to another as required. With three tanks of the dimensions given above, six or seven hundred pike perch of average size can be transported.

For coating these tanks inside, as well as all tanks and troughs about the hatchery, coal tar with about one-third its bulk of good spirits of turpentine, free from benzine, is applied as hot as it can be made. This forms a smooth, hard, strong, impervious coat which lasts well, and is cheaper than asphaltum varnish.

The use of a proper dip net in handling the fish is of great importance. The splitting of fins and removing of scales is to be avoided as far as possible where any species of fish is to be penned. The scales of the pike perch are not so easily abraded as those of the whitefish, but it suffers even more as the result of injuries, owing to the higher temperature of the water at the time it is penned. The ideal net would be made of cofferdam rubber of suitable thickness, perforated at frequent intervals so as to permit the free discharge of the water—that is, a rubber net—but where many are necessarily in use and subject to rough handling, especially in freezing weather, their expense would be considerable. The hoop of the net used at the Put-in Bay station is of ⅜-inch spring steel wire, that being the stiffest and strongest material obtainable of its weight. It is bent in the form of a parallelogram 22 inches long and 20 inches wide, with rounded corners. This is fastened

into an ash handle about 6 feet long. The bag is of cider-press cloth (which is made of large, soft twisted thread, loosely woven), with each alternate thread over a considerable space in the center of the net pulled out. The bag is fastened to the hoop with small copper wire, as twine is soon cut off in working around the nets and pens. The bag of the net is 8 or 10 inches, for if much more is given it will let the fish form a pocket against the wire and prevent an easy discharge.

Netting with a 1-inch mesh and large thread has proved to be a failure, the tails of many fish being split by it. It is believed that netting with a very small mesh and the largest thread that can be woven will do the work well, the greatest objection being the knots, which injure tender species.

A frame made like a stretcher, with gunny cloth tacked on in such a manner as to bag about 2 feet, is convenient for holding fish preparatory to spawn-taking. It should be about 6 feet long and 3 feet wide, making the bag 3 by 4 feet, with handles 1 foot long at each end.

A gate made of light stuff as long as the pens are wide (8 feet) and 2 feet deep, covered by ordinary netting drawn taut and fastened by small staples, is useful in sorting the fish in the pens. The false bottom is lifted and fastened in place with the pins. There will now be about a foot of water over the floor and 1 foot of the top of the pen will be out of water. Beginning at one side the gate is gently moved along until the fish are all confined in a sufficiently restricted space. They are sorted, the ripe fish placed in the "stretcher," preparatory to stripping them, the medium in a tub to be taken to the proper pen, and the hard, which it is assumed will be in the majority, are put back over the gate into the same pen they were taken from.

The pens are numbered and a careful memorandum kept of the fish, the number of males and females received from and turned back to the fishermen each day, the number stripped, and the number in each pen.

All unnecessary noise near the pens must be avoided, especially jars or discharge of firearms, and no one should go near them except in the performance of duty. The quieter fish are kept and the less and the more gently they are handled the greater the chances of procuring a large number of good eggs, while the opposite course will cause many "plugged" females and failure generally. In transferring the fish from one net or receptacle to another it is preferable to handle only one at a time, except when they are small.

Fish, particularly females, taken from a depth of from 30 to 35 feet, often come to the surface of the water in the pens and can not descend, owing to the expansion of air in the swimming bladder. The pressure may be relieved without injury by inserting a small-sized aspirating needle, at an angle of about 45°, through the flesh of the fish into the bladder, about halfway between the middle of the spinous dorsal and the lateral line. The air can be heard escaping and when the sound ceases the needle may be removed.

U. S. COMMISSION OF FISH AND FISHERIES,

GEORGE M. BOWERS, Commissioner.

ARTIFICIAL PROPAGATION

OF

MARINE SPECIES.

Extracted from the Revised Edition of the Fish Manual.
Pages 195 to 238, Plates 54 to 63.

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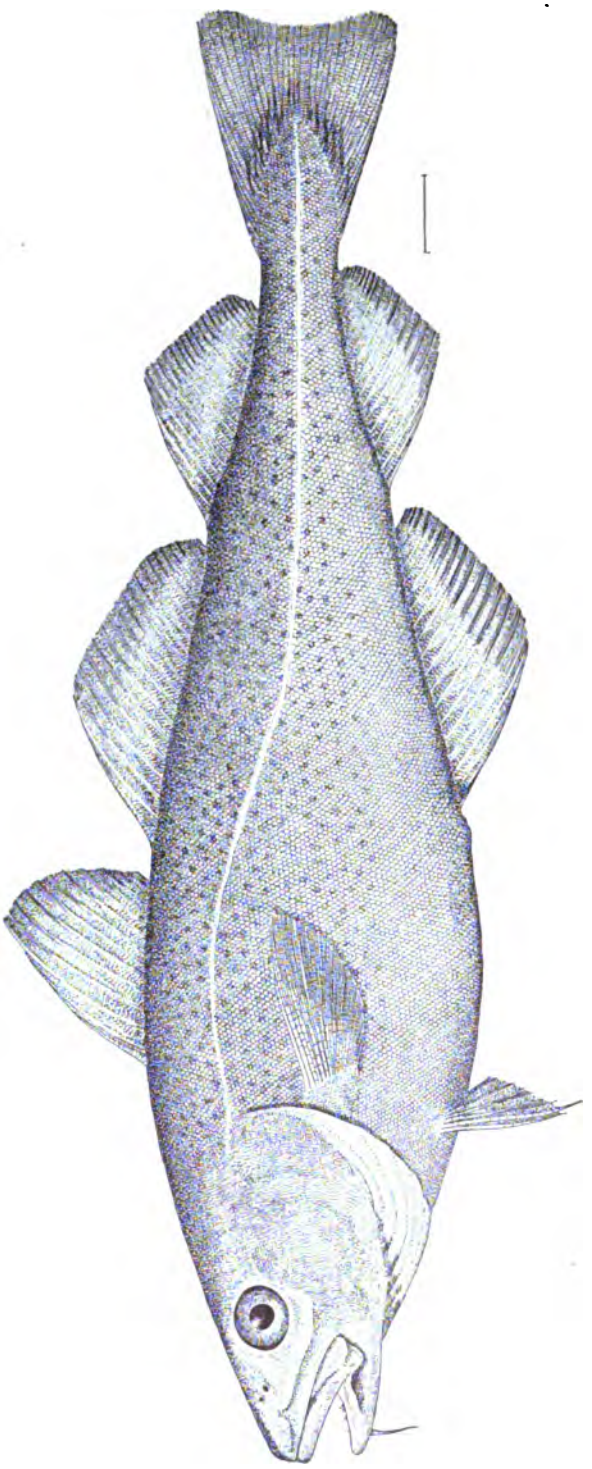


GADUS CALLARIAS. *Cod.*

THE COD.

DESCRIPTION OF THE FISH.

The body of the cod is moderately long, compressed and tapering behind; the greatest depth is about one-fourth its length. The large head is narrowed anteriorly and is contained 3½ to 4½ times in the body length. The mouth is large; the lower jaw is included within the upper when the mouth is closed; the maxillary extends to about middle of eye. The diameter of the eye is about half the length of the snout and one-fifth that of the head. There is a conspicuous barbel on the chin. The number of dorsal fins is 3 and of anal fins 2; the dorsal rays are usually about 14, 21, and 19 in the respective fins, and the anal rays are 20 and 18. The ventral fins are well developed, with about 7 rays. The cycloid scales, with which the body is covered, are very small. The air-bladder is large and thick. The color varies greatly, depending on food, kind of bottom on which found, and other conditions. Fish taken offshore in deep water are usually olivaceous on the back and whitish beneath; the so-called rock cod, found in shoaler water among rocks and kelp, vary in color from green to deep red. The back and sides are covered with small, round, reddish-brown spots. The lateral line is conspicuous, of a whitish color. The fins are dark.

From other species of the family, taken in the same waters, the cod is readily distinguished. From the haddock it differs in having a pale, instead of a black, lateral line; in its spots (absent in the haddock), and in its larger maxillary bone, which reaches past the eye, while in the haddock this bone does not extend to the eye. The features distinguishing the pollock from the cod are the smaller size, the projecting lower jaw, the uniform coloration above, the sharp snout, the smaller barbel, etc. The hakes have only 1 anal and 2 dorsal fins, a filamentous prolongation of the first dorsal ray, and a ventral fin consisting of two or three very long filamentous rays.

The status of the cod of the North Pacific Ocean is somewhat uncertain. It has generally been considered identical with the Atlantic species, but its smaller air-bladder and other features may entitle it to recognition as a distinct species.

RANGE, MOVEMENTS, FOOD, ETC.

Cod are widely distributed in the North Atlantic Ocean. To the north they range far beyond the Arctic Circle, and to the south as far as Cape Hatteras, although they are not common south of New Jersey.

The cod of the North Pacific Ocean is found from Bering Sea south to Oregon and Japan.

The movements of cod are not well understood. They go in schools, but in much less dense bodies than do mackerel, herring, and menhaden, and when moving from one ground to another they are in more compact schools than when on the feeding-grounds. The movements on and off shore and from bank to bank are due to several causes, among which are the effects of water temperature, the presence or absence of food, and the spawning instinct. In the winter months there is a well-marked movement of large bodies of codfish to the shores of the New England and Middle States, and important fisheries are there carried on in regions from which cod are absent at other times. This movement seems to be chiefly for the purpose of finding shallow grounds for spawning. That the cod sometimes makes very long journeys is shown by their capture on the New England coast with peculiar hooks in their bodies which have been identified as similar to the hooks employed by the French cod fishermen on the Grand Banks.

Although sometimes found in shallow water, cod are essentially deep-water fish, preferring water from 20 to 70 fathoms deep and being found even at a depth of 300 fathoms. Those caught for market are usually taken at depths of 20 to 40 fathoms.

The cod takes its food on the bottom, at the surface, or at intermediate points. It is an omnivorous and extremely voracious feeder, consuming all marine animals of suitable size. Favorite articles are bivalve mollusks, crabs, lobsters, starfish, and fish. Among the fish consumed in large quantities are capelin, lant, herring, alewives, menhaden, mackerel, and haddock, although many others are also eaten. The abundance and movements of such fish have an important relation to the presence and abundance of cod in a given region.

WEIGHT AND GROWTH OF COD.

The largest cod recorded from New England waters weighed 211½ pounds and was over 6 feet long; it was taken on a trawl off the northern Massachusetts coast in May, 1895. The capture of a number weighing from 100 to 175 pounds could be cited, but those exceeding 100 pounds in weight are by no means common, and even 75-pound cod are not numerous. The average weight of the large-size cod caught in the shore waters of New England is about 35 pounds; on Georges Bank, 25 pounds; on the Grand Banks and other eastern grounds, 20 pounds; the average weight of the small-size fish caught on all these grounds is about 12 pounds.

Observations in Massachusetts of the rate of growth of the cod show that those 1½ to 3 inches long are about 6 months old; those 9 to 13 inches long, and weighing 7 or 8 ounces, are 1½ years old; those 18 inches long, and weighing 2 to 2¼ pounds, are 2½ years old; and those about 22 inches long, and having a weight of 4 to 5 pounds, are 3½ years old.

SPAWNING.

The principal spawning time of the cod on the New England coast is winter, but the season begins as early as November and continues until April. Spawning fish are occasionally caught from October until May. The spawning period for an individual fish is greatly prolonged, and probably covers six or eight weeks, only a small percentage of the eggs maturing at one time. The male and female cod may attain sexual maturity when weighing only 3½ or 4 pounds. The ages of normal fish having these weights are supposed to be three to four years.

When impelled by the spawning instinct, the cod seek the shoal waters of the coast or banks in schools consisting of both sexes. The female is less active than the male at this period, and probably rests quietly on the bottom while discharging the eggs. There is no evidence to show that the sexes are paired or in close proximity during the act of spawning. On the contrary, it seems likely that fertilization is generally accomplished by accidental contact of the sexual products as they are swept about by the elements, having risen to or near the surface as soon as extruded.

The cod is one of the most prolific fishes. The ovaries of a 21-pound fish have been computed to contain 2,700,000 eggs, and a 75-pound cod has been estimated to have 9,100,000 eggs, these figures being deduced by careful weighing or measuring of a known number of eggs. The egg is from $\frac{1}{19}$ to $\frac{1}{17}$ inch in diameter, the smallest fishes having the smallest eggs; the average size may be taken as $\frac{1}{18}$ inch. The approximate number in a fluid quart is 337,000.

The destruction of cod eggs in nature is necessarily large. The principal loss is probably through failure of impregnation, the eggs losing their ability to become fertilized and the milt its vitality very soon after being thrown from the fish. Incalculable numbers are thrown on the shore by the waves and there die. Cod eggs are also destroyed by numerous animals, including fish, birds, and invertebrates.

COMMERCIAL IMPORTANCE AND FOOD VALUE.

The cod is one of the most valuable of all food-fishes, and in the United States ranks as the most prominent commercial fish. In the matter of persons engaged, vessels employed, capital invested, and value of catch, the taking of cod in the United States is more extensive than any other fishery for fish proper.* The number of vessels which fish wholly for cod or take cod in noteworthy quantities, together with other "ground fish," is not less than 600, of over 25,000 net tons burden, carrying about 7,000 men, and with a value of $3,000,000, besides which there are very large fisheries carried on from boats and small vessels of less than 5 tons burden. The approximate annual value of the cod

* The oyster fishery is the most important branch of the fishing industry of the United States.

catch in 1898 was about $2,000,000, a sum representing the first value of the fish. The weight of the fish as landed from the vessels (fresh, split, and salted) was about 96,000,000 pounds.

The cod fishery is prosecuted in all the coastal States from Maine to New Jersey, being most important in Massachusetts and Maine. Gloucester and Boston are the principal fishing centers. On the Pacific coast there is an important fishery in Alaska, carried on by San Francisco vessels.

Cod are taken with hand and trawl lines, baited with fish, squid, etc., and fished from small boats or the vessel's deck. The principal grounds in the Atlantic are the famous "banks"—Grand, Georges, Western, Quereau, etc.; on the Pacific coast the Shumagin Islands are the chief grounds. Small quantities are taken in traps at places on the New England shore.

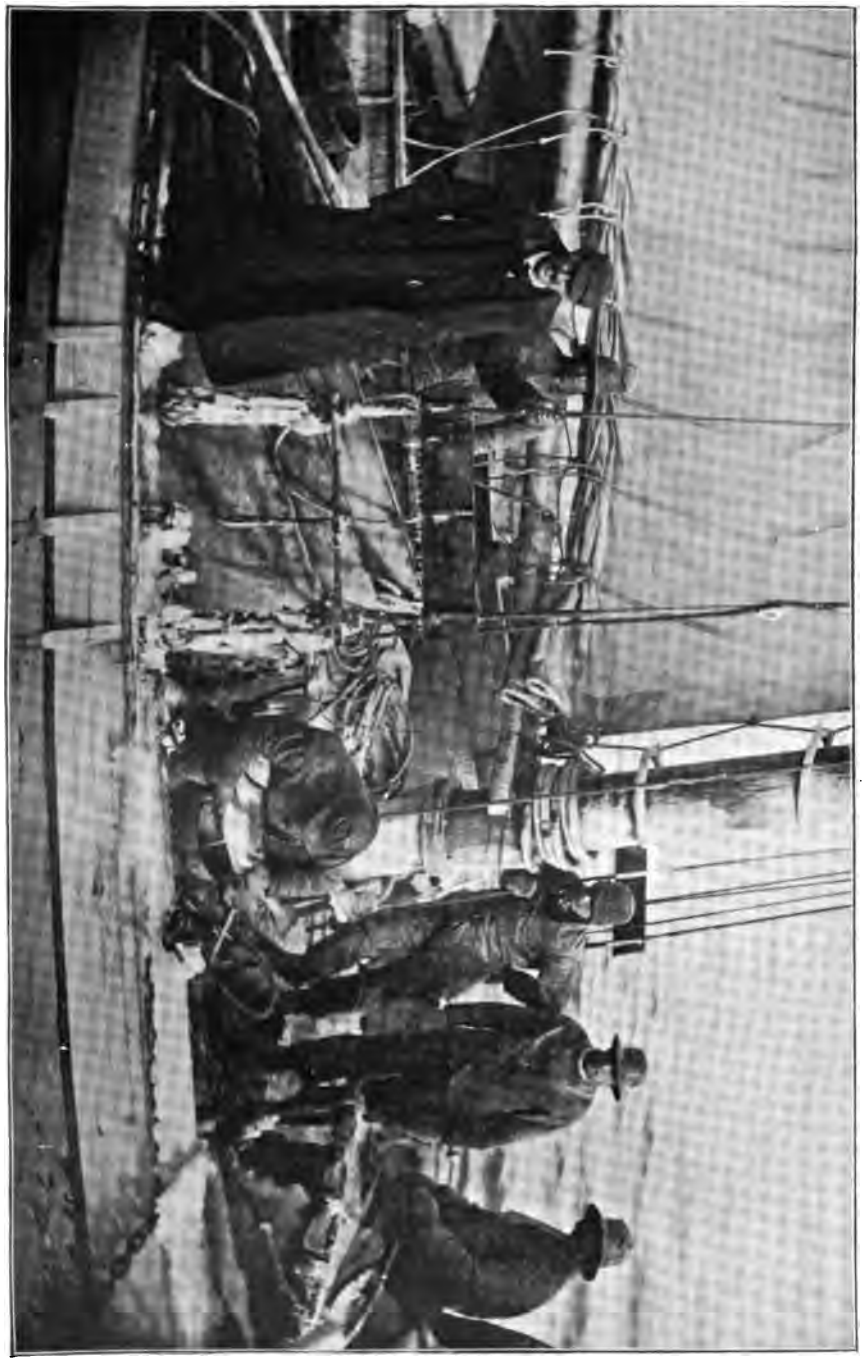
ARTIFICIAL PROPAGATION.

The cod is propagated artificially on a more extensive scale than any other marine fish. Artificial hatching was first undertaken at Gloucester, Massachusetts, in the winter of 1878–79, and has since been regularly prosecuted on an increasingly large scale at both Gloucester and Woods Hole. Up to and including the season of 1896–97, the number of cod fry liberated by the Commission on the east coast was 449,764,000. The output of fry in the last-named year was 98,000,000. The unmistakable economic results which have attended these efforts warrant all the time and money devoted to them and justify the greatest possible expansion of the work.

COLLECTING EGGS ON THE FISHING-GROUNDS.

The following methods are pursued in collecting cod eggs for the United States Fish Commission station at Gloucester.

As cod are abundant in Ipswich Bay during the winter, vessels from Gloucester, varying in size from 10 to 70 tons, engage in fishing there, starting from Kittery Point, Maine, or Portsmouth, New Hampshire, where they market their catch, secure bait, and obtain supplies. At the beginning of the cod season (which usually opens from the middle to the last of November) arrangements for the board of the men, dory and building hire, transportation of eggs, etc., are made with persons at Kittery Point and permission to place spawn-takers aboard the fishing vessels is obtained, with the understanding that they will be allowed to take eggs from the fish secured, that they be given the freedom of the vessel in order to properly care for the eggs, and that no charges be made against the Commission except that 25 cents be paid for each meal furnished the spawn-takers. After these arrangements are made the men are directed to board such of the fleet as are at the time meeting with the best fishing, but as the fish are not of uniform abundance in the bay it is necessary to keep a vigilant watch on each vessel's catch as it is landed, daily, to know where to place the spawn-takers to the best advantage.



STRIPPING COD ON VESSEL.

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A spawn-taker's outfit consists of a water bucket or pail, a dipper, a siphon, a thermometer, and a tin spawn-kettle about 2 feet long, 1 foot wide, and 8 to 9 inches deep; the kettle has a cover and handle.

When new spawn-takers are employed they are instructed in the work and sent out in vessels with the experienced men to familiarize themselves with the methods. The spawn-takers ordinarily leave their boarding-places at 1 o'clock in the morning (though the time varies somewhat, according to the weather) and join the boats anchored in the harbor of Kittery or at Portsmouth. During moderate weather the men frequently go aboard before midnight, as the vessels must sail when the tide is favorable, to avoid getting becalmed or meeting a head tide, either of which might prevent them from reaching the fishing-grounds in good season.

After joining the vessels, the spawn-takers usually assist the fishermen in getting under way, managing the ship, etc., and on reaching the place where the nets or trawls are set—usually 6 to 10 miles distant—the spawn-takers help the crews in hoisting out and dropping the dories on the gear as each buoy is reached, the men remaining on the vessel's deck with the captain while the fishermen are hauling or under-running their gear, and until they return to the vessel with the fish.

As soon as the dories begin to arrive with fish, the work of the spawn-taker begins. As the fish are pitched aboard, the spawn-taker stands ready to examine each one and select those that may contain ripe eggs or milt. As the dories are usually picked up in the same order in which they are dropped, there is opportunity to strip the fish without much hurry, but sometimes several are picked up in a short space of time, and if a large quantity of fish is landed the catch remains on deck until the spawn-taker can overhaul it. In bad weather, however, when the fish would be in danger of being washed away, they are put in bins on deck and can be pitched from one bin to another by the spawn-taker as the condition of each is determined. Usually one of the crew assists in this work and often renders valuable assistance. Great care is taken not to get any green or dead eggs with the good ones and to keep the eggs as free from foreign matter as possible; but in rough weather, when the vessel is pitching or rolling heavily, vigilance in these respects is necessarily somewhat relaxed.

The spawn-taker seizes the fish by the tail, places the head under the left arm, if it is not too large, leaving the right arm free for stripping the fish, which is done in the usual way. Only live fish or fish recently dead are used.

The eggs are first taken in a common pail, the inside of which has been moistened with water. Then a sufficient quantity of milt to fertilize the eggs is added and thoroughly mixed with them and allowed to remain from 10 to 20 minutes, or longer, after which water is added and the eggs are carefully cleaned by siphoning off the old water and putting in fresh water until all the slime and milt are drawn from the pail. The good eggs, which rise to the surface of the water, are

then transferred to the spawn-kettle containing clean water and the poor or dead eggs are thrown away.

All the eggs obtained on a given vessel are kept in the kettle until the receiving-house on shore is reached, the water on the eggs being changed at intervals during the passage in; and to keep the temperature uniform, the eggs are shifted from one part of the vessel to another, according to conditions. Sometimes, when the sea is very choppy or rough, the pail can not safely be used, as the eggs will spill out, and they are then stripped directly in the spawn-kettle and cleaned as well as possible.

It was formerly the practice to take cod eggs in a small quantity of water, but during the season of 1896–97 it was determined to test the relative efficacy of the so-called wet and dry methods of fertilization. Some of the spawn-takers were instructed to employ the dry method and others the wet method. The experiments show that when eggs were taken by the dry method a much larger percentage was fertilized than when taken in water. Eggs from fish caught on trawl lines invariably yield a larger percentage of fry than those from fish caught in nets, although fine eggs are frequently obtained from net fish. The explanation seems to be that fish caught in nets soon become entangled and are either drowned, or nearly so, shortly after being meshed; they struggle a great deal more than fish on trawls and the greater part of them are dead when taken into the boats, many of them being scaled, which indicates severe exertion in trying to escape. Trawl fish, on the other hand, are almost always alive and active when taken from the water, and very few fish without scales are found unless the gear has been out a long time or has been set during a heavy storm, when, of course, many of the fish will be dead.

Better results are obtained from eggs taken when the weather is fairly cold than when it is warm, as when the temperature is high it is difficult for spawn-takers to keep the water containing the eggs at a safe temperature, and before the egg house on shore is reached there is almost always a heavy loss. When the weather is too cold for eggs to be kept on the vessel's deck the spawn-takers put them below the deck, where the temperature will be suitable.

Many difficulties and much exposure are encountered by the men who collect cod eggs on the fishing vessels, and during severely cold and windy weather, when the deck is covered with ice and the fish freeze stiff in the dories before they reach the vessel, it is practically impossible to get good eggs. During boisterous weather, when the fleet succeeds in hauling the gear only once or twice a week, the greater part of the catch is generally dead when taken. A spawn-taker often secures a good lot of eggs and can find no ripe milt fish, but in this event he will, if the weather permits, visit the nearest vessel in quest of milt. Sometimes there is a school of milt fish in the bay and very few female fish, and a vessel may catch several thousand pounds of cod day after day without finding ripe spawn in any of them, while another

HATCHERY AT GLOUCESTER—VIEW FROM GLOUCESTER HARBOR.

vessel, fishing only a short distance away and not catching many fish, will get a comparatively large number of spawners.

The spawn-takers are instructed not to take eggs from fish that have died on trawls or in nets, although fine lots of eggs are often taken from fish that die in the dories before they reach the vessel, showing that the eggs do not die immediately after the fish expire. The vitality of the eggs after the death of the fish varies in different cases and depends on the conditions of the eggs and the fish at the time the fish are caught, the state of the weather, etc. An experienced spawn-taker can almost always distinguish readily between good and poor eggs, although it is not always possible to determine whether or not a given lot of eggs will live. As the weather and the nature of the school of fish in the bay regulate the collection of eggs, the results of a season's work can not be estimated in advance. It has been observed that roe fish are found in largest numbers previous to an easterly storm and when the wind is from the south or west. During heavy westerly winds cod appear to approach quite close to the beach, and when the wind blows from the eastward and the sea begins to rise, they leave for deeper water.

When fishermen are hauling their nets and trawls, they frequently notice spawn being emitted from fish when they are landed in the dories. Such fish are laid away on their backs in the stern of the boat and when the vessel is reached are carefully passed to the spawn-taker, many eggs that would otherwise be lost being thus saved.

When the price of fish is low at Portsmouth or the wind is unfavorable for making that harbor, some of the fleet go to Rockport to sell their fish, and should spawn-takers be on such vessels they immediately take their eggs to Gloucester when the vessels arrive in Rockport.

Usually the fishing vessels return to Kittery Point between 1 o'clock and 10 o'clock p. m. Immediately on landing, the spawn-takers carry their collections to the egg-house on shore, where the spawn is carefully examined, cleaned, packed, and shipped to Gloucester by first train. In shipping eggs large fruit jars are used. About 350,000 eggs are put in each jar, the jar is filled with water, the top is securely fastened, and the jar is placed horizontally in a large iron kettle made especially for the purpose and holding five jars. The jars are wrapped in burlap before they are put in the kettles, to prevent them from breaking, and, when necessary, snow or ice is put in each end of the kettles to keep the temperature uniform during transit, but it is not allowed to come in direct contact with the jars.

A messenger usually accompanies the eggs and gives them constant attention until they are delivered at the station. The snow or ice is removed from the kettles, if the temperature falls too low, and replaced, if necessary, the messenger making frequent use of a thermometer.

In preparing eggs for shipment without messenger, they are first cleaned carefully by drawing off all dead eggs or dirt, then put in large fruit jars in the same manner as when they are shipped to Gloucester, and the jars are packed horizontally in large wooden cases holding nine

jars each. Rockweed or moss, together with ice or snow, is used in packing them, the former being placed around the jars and the latter put in the bottom, sides, and top of the case to keep the eggs cool. Successful shipments are often made by express.

Some difficulty has been experienced in keeping large lots of eggs over night at Kittery Point, as the facilities are insufficient for changing water or for spreading the eggs out to overcome the injurious effects of prolonged crowding; but when it is necessary to so retain them, they are put in McDonald jars in which the water is changed as often as the supply will permit. As the water in the harbor is partly fresh and unfit for this purpose, it is necessary for spawn-takers to bring in a supply from the open bay in large transportation cans.

CAPTURING AND PENNING BROOD COD.

Practically all of the cod fry hatched at Woods Hole prior to 1896 represented eggs taken from penned fish. Some of the cod collected for breeders are caught by the crew of the Fish Commission schooner *Grampus* and some are purchased from commercial fishermen. Two or more smacks usually engage in fishing for the station during the collecting season, which is from about October 1 to November 30. The grounds resorted to are east of Nantucket and around Block Island. The fish are taken with hand lines fished from the deck while the vessel is drifting, in water from 10 to 40 fathoms deep. Those taken in the shoaler water are preferable to those coming from deep water, as the change to the shallow cars in which they are held at the station is less pronounced. Great care is exercised in catching the fish, for when hastily hauled up from deep water they are very liable to be "poke-blown," that is, they have their stomachs turned inside out through the mouth. When drawn in with moderate speed, they become adapted to the gradually diminishing pressure and do not suffer injury. It is also important in unhooking the fish not to injure its mouth any more than is absolutely necessary, as the wound caused by the hook frequently spreads and forms a large sore and eventually kills the fish. All the vessels which collect cod for the station are provided with wells in which the fish are placed and held while in transit.

When a vessel arrives at the station with cod, the fish are immediately transferred with dip nets from the well to live-cars 16 feet long, 6 feet wide, and 5 feet deep, which are constructed of wood and divided into two compartments by a crosswise partition. As the fish obtained from smacks are paid for by the pound, it is customary to weigh about 10 per cent of each load and estimate the total weight by the average of those weighed. While being weighed, the cod are also counted, about 500 being put in each car. The cars are moored in the middle of a pool or basin protected on all sides by a wharf, which breaks the force of the sea in stormy weather and affords a sheltered place for handling the fish and taking the eggs.

Cod take little or no food when spawning. The impounded brood fish are often tempted with fresh fish and with fresh and salted clams,

but they can rarely be induced to eat. A certain percentage of the penned fish die and are removed at once from the cars. The development of the sexual organs is noted when the dead fish are taken out. Fish about ready to spawn are placed in a separate car and carefully watched. They are examined two or three times a week and any ripe eggs are taken.

In taking and fertilizing the eggs of brood cod the same general methods are followed as are adopted on the fishing vessels in Ipswich Bay. The spawn-taker grasps the ripe fish near the tail with his left hand and holds the fish's head either between his body and left arm or between his thighs, using his right hand to strip the fish. The eggs are usually taken in a bucket. Both the dry and wet methods of fertilization are used at Woods Hole. Usually about 80 per cent of the eggs taken are fertilized. Unlike many other fishes artificially propagated, the cod does not yield all of its eggs at one time. After expressing all the eggs possible from a given fish, it is returned to the live-car, and in a few days will have matured more eggs, which are then taken. When the ovaries have discharged all their eggs, the fish is released.

In recent years from 1,600 to 9,000 cod have been penned annually in the protected basin at Woods Hole. Only from one-ninth to one-third of these, according to the season, yield good eggs.

CHARACTERISTICS OF COD EGGS.

Cod eggs are nearly transparent, and float at the surface of the water when first taken. They vary in color from a pale green to a deep red, those having the green color being the best. Good results are seldom obtained from the red eggs, and those of a deep red color almost invariably die in three or four days after being received. Unless the density of the water is low, the eggs normally float during the entire hatching period. However, it frequently happens that, owing probably to the accumulation of sediment, the eggs gradually sink during the last third of the incubation period, and finally mass together on the bottom of the hatching-box; here they would quickly smother but for the current.

Floating eggs are not necessarily good ones, for unfertilized and injured eggs usually float 18 to 36 hours before going to the bottom. Unfertilized eggs may be readily detected, as they have no disc which marks fertilization and have a milky appearance. The dead eggs quickly sink, and are easily distinguished from the sound eggs by a white spot in the center.

Eggs received at the hatchery are transferred from the vessels in which they came to Chester jars partly filled with water, and in 10 or 15 minutes they rise to the surface in a dense mass. The eggs are put in each jar to the depth of an inch, a quantity representing approximately 379,000 eggs. If the hatchery is full, about a fifth more eggs may be put in a box, the maximum number that may be safely carried being 450,000. The first measurements are carefully made, as they form the basis for subsequent estimates. As soon as the eggs are measured they are transferred to the hatching-boxes with dippers.

THE APPARATUS USED IN HATCHING COD.

The apparatus and methods employed in cod-culture are the outgrowth of long experience and study and have as their special features the closest possible simulation of natural conditions. The apparatus now in general use is the so-called McDonald or automatic tidal box. The boxes are constructed in series of 12 or less, the number depend-

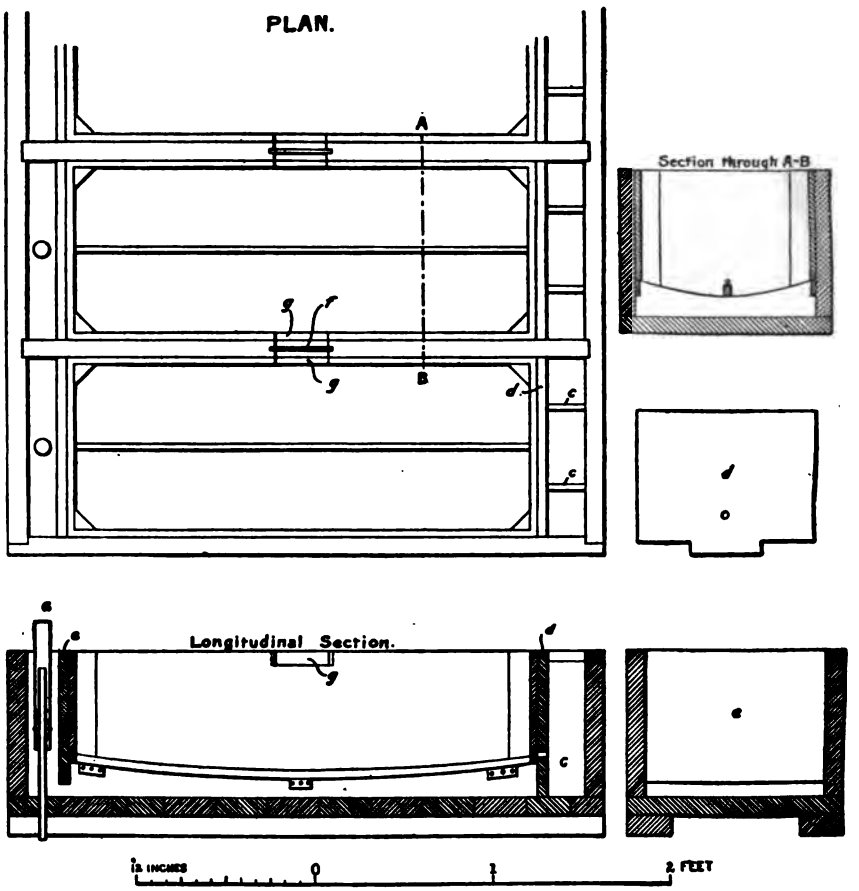
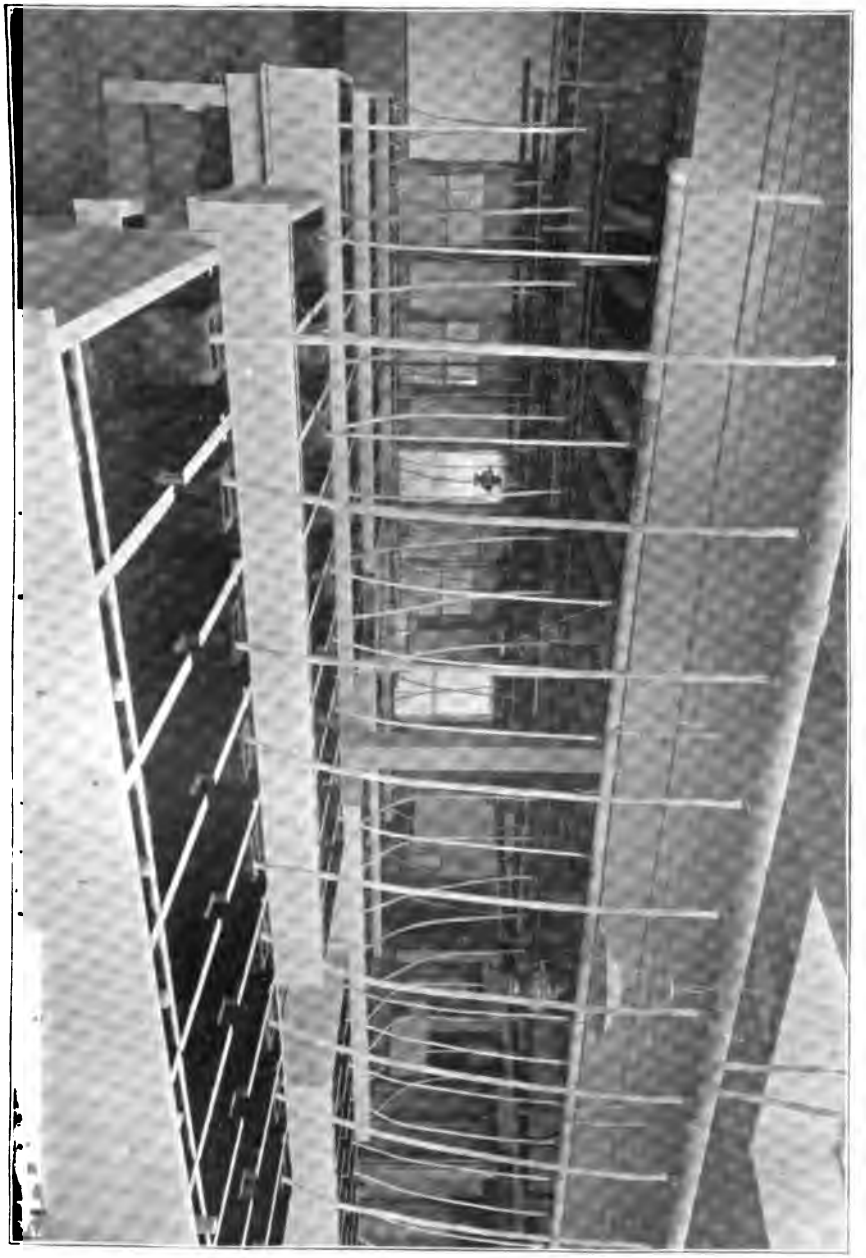


Diagram of Tidal Cod Hatching-Box.

A-B Points where cross-section is taken.
a, siphon.
c, partitions forming upper pockets.
d, partition forming space at upper end of compartment.
e, partition forming space at lower end of compartment.
f, glass gate.
g, slot between adjoining compartments.

ing on the size of the hatching-room, the arrangement of the hatching-tables, or other conditions. The Gloucester hatchery has 8 tables of 9 boxes each, and Woods Hole 14 tables of 12 each. At Gloucester 25,000,000 eggs can be hatched at one time, and at Woods Hole 65,000,000. For a wooden framework to accommodate 9 boxes such as are used at Gloucester the outside dimensions are: Length, 10



INTERIOR VIEW OF GLOUCESTER HATCHERY—SHOWING COD BOXES IN OPERATION.

feet; width, 3 feet 8 inches; depth, 11 inches. The table or trough is constructed of 2-inch lumber and raised to a convenient height by short, stout legs. The table is divided into 9 water-tight compartments by means of crosswise partitions of 1½-inch plank.

At Woods Hole the dimensions of the troughs containing 12 boxes are as follows: Length over all, 13 feet; width, 2 feet 7 inches; depth, 12 inches. The plank is 1½ inches thick. The bottom of the trough is 2½ feet above the floor. The compartments are separated by 1¼-inch partitions and are 22 inches long, 12 inches wide, and 10¾ or 11 inches deep.

Two inches from each end of each compartment there is a 1-inch wood partition. The partition *d* at the supply or upper end of the compartment extends with its middle portion to the bottom of the trough, while the two sides extend only to within 1½ inches of the bottom. The partition *e*, at the discharge or lower end of the compartment, extends its full length to within 1½ inches of the bottom of the trough. Between the two partitions *d* and *e* in each compartment there is snugly fitted a movable box in which the eggs are placed. This box, which is constructed of ½-inch plank, is 9 to 9½ inches deep in the center, but only 8 inches deep at the corners, the bottom sloping upward toward the sides and ends of the box and being covered with linen scrim. A wooden strip at the bottom, ½ inch thick and conforming to the shape of the bottom of the box, extends the length of the box. The box rests on cleats in the corners of the compartments which keep the center of the box 1½ inches above the bottom of the trough.

The space at the supply end of each compartment is divided into three pockets by 1-inch wood partitions. The middle pocket connects with the main compartment by means of a small hole ($\frac{3}{16}$ to $\frac{8}{16}$ inch) through the center of the partition and end of the box immediately above the lengthwise strip, and the two lateral pockets connect by a space at the bottom with the main compartment.

At Woods Hole the water used in hatching is pumped from the harbor to two tanks of about 18,000 gallons joint capacity. The water is led to the hatching-room through a 4-inch wooden pipe and is supplied to the hatching apparatus through a 2½-inch hard-rubber pipe which branches from the main pipe and runs directly over each row of tables. At Gloucester the main supply-pipe is of hard rubber, 3 inches in diameter; this leads from a tank of 15,000 gallons capacity, the bottom of which is about 6 feet above the level of the troughs. A small soft-rubber tube, provided with a rubber pet-cock, carries the water to the middle pocket at the back of each box. As the pocket is always full of water when the boxes are in operation, a considerable amount of water goes through the small hole with much force, creating a strong current in the box and keeping the eggs in constant rotary motion. This current is one of the principal features of the apparatus.

Much more water enters the middle pocket than can pass through the small hole into the box, and the surplus flows over the sides and

enters the main compartment from below, coming up through the scrim-covered bottom into the movable box.

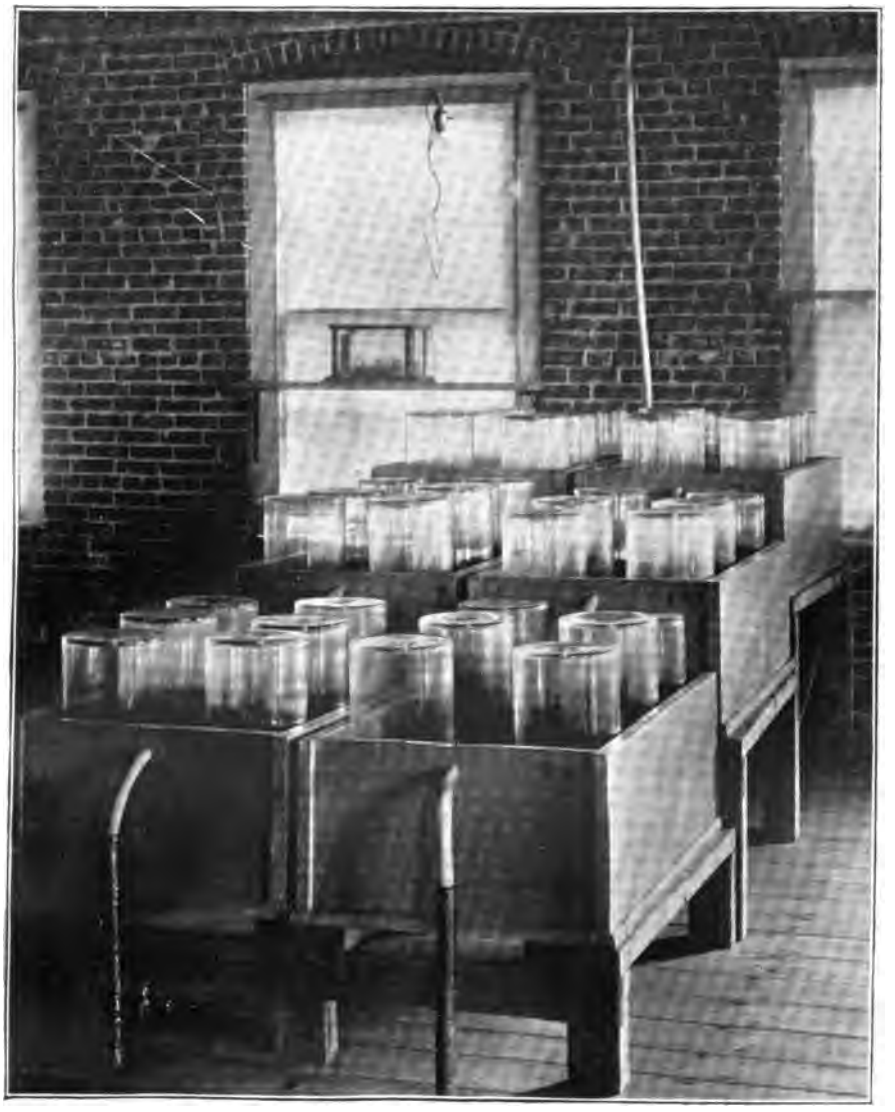
The partition forming the pocket at the lower or front end of the box only extends to within 1½ inches of the bottom, leaving a space through which the water runs from the compartment. In the bottom of the pocket there is an opening in which the vertical waste-pipe fits. This pipe is brass, ½ inch in diameter and 10 or 11 inches long; the top of the pipe is 7 inches above the bottom of the table. The waste-pipes from the different boxes discharge into a trough which carries the water from the building.

A particularly important part, and the one which gives the name "tidal box" to the apparatus, is used in conjunction with the waste-pipe. This is a brass siphon-cap, which fits over the upper end of the waste pipe. The cap is a tube, closed at the top, 9 inches long and 1¼ inches in diameter. It is kept at any desired height on the waste-pipe by wire springs in the cap or by other means.

By virtue of the siphon attachment the water in each box rises to the height of the top of the waste-pipe and begins to run over. This partly exhausts the air in the cap, more water rushes in, and the pipe becomes filled with water; then the siphon begins to act and takes off the water to a level of the bottom of the siphon-cap. Usually the cap is pushed about half down the waste-tube, although the height of the water in the box after the discharge of the siphon is regulated by the manner in which the eggs are working. About 7 minutes are required for the water to be drawn down and the box to again fill, and approximately two-fifths of the water is taken off at each discharge. By this arrangement the water in the boxes is constantly rising and falling automatically; the movements of the waves are thus simulated, the eggs are kept in constant circulation, and fresh water is continually entering the boxes.

The Chester box was generally used in cod-culture up to a comparatively recent date, and is still occasionally employed in marine fish-cultural operations. The general object of its construction is the production of an automatic rise and fall of water, as in the McDonald box, although it differs from the latter in some essential particulars. It consists of a box of variable dimensions in which jars are placed for the reception of the eggs. A convenient size of box is 7½ feet long, 2 feet wide, and 2⅓ feet deep. From 4 to 8 large glass jars are arranged on wooden supports 7 or 8 inches above the bottom of the trough. Smaller boxes, to accommodate only 2 or 4 jars, are also used. The jars are about 9 inches in diameter and are of two heights—9 inches and 17 or 18 inches; they have straight sides and a flat bottom with a central half-inch hole.

The jar is placed in the box in an inverted position, with its bottom above the level of the top of the trough. The sea water supplying the trough enters the compartment at one end of the trough and escapes



CHESTER BOXES.

by means of a siphon in the other compartment, running through a hole several inches below the top of the trough. The trough fills with water up to a level with the hole, when the siphon begins to act and takes off the water more rapidly than it enters, to a level with the inner end of the siphon, the fall being 4 to 5 inches. Air then enters the siphon, and it ceases to act until the water has again risen to the height of the discharge hole. The water thus rises and falls in the jars automatically, the interval between the successive discharges being regulated by the length of the inner arm of the siphon, the size of the tube, and amount of water supplied.

After the eggs are introduced into the jars a piece of cheese-cloth or linen scrim is placed over the top, and fastened by means of rubber bands. The jar is then inverted and placed on the wooden supports provided for the purpose, and the plug in the bottom removed to allow the escape of the air and the rise and fall of water. The number of eggs per jar is about 190,000 or 200,000.

DEVELOPMENT OF THE EGG.

The development of the cod egg is greatly influenced by the water temperature, which fluctuates from day to day and makes it difficult to state exactly when the eggs will hatch. With a high temperature the advancement of the egg through the different stages proceeds rapidly and can readily be appreciated with the unaided eye, while with a low temperature the development is slow and may be greatly prolonged by very cold water. With a mean temperature of 47° cod eggs begin to hatch in 11 days, although 2 or 3 additional days are usually necessary for all the eggs of a given lot to hatch. At 43° the time is 14 or 15 days, and at 38° it is 20 to 23 days. The best results are obtained when the temperature ranges from 41° to 47°. The hatching proceeds satisfactorily with the water at 38°, but with a lower temperature the incubation period is so long that the fry are very weak. On the natural spawning-grounds the water seldom gets below 38°, while at the stations after January 1 the water used for hatching rarely gets as warm as 37°, and often is as low as 31°; from the middle of January to the latter part of February it remains at about 32°. Since it is impossible to do even fair work when the water gets below 35°, it has been the practice to warm the water by passing it through a coil of pipe contained in a tank of warm water or by introducing steam directly into the water pipe whenever the hatchery water gets below 37°.

The water being at 47°, during the first 4 days the egg passes through the different stages of segmentation; at the end of that time the germinal area begins to assume the general form of a fish; and by the ninth day the fish is quite well formed, and may be readily seen with the naked eye. By the tenth day the embryo shows signs of life, and under the microscope the heart may be seen to beat.

Following is a table showing the approximate time required for cod eggs to hatch, with the water at the stated mean temperatures:

Mean water temperature.	No. of days.	Mean water temperature.	No. of days.	Mean water temperature.	No. of days.
31° F.	50	37° F.	23	43° F.	14
32° F.	40	38° F.	21	44° F.	13
33° F.	35	39° F.	19	45° F.	12
34° F.	31	40° F.	17	46° F.	11
35° F.	28	41° F.	16	47° F.	10 or 11
36° F.	25	42° F.	15		

Moderately clear water is essential to the healthy development of the fry. If much sediment is present it collects on the eggs and acts very injuriously, often killing them. Sometimes eggs become so coated with sediment that the fry appear to be unable to burst the shell; some lots of eggs thus affected have been known to retain fry fully two weeks beyond the normal period of incubation.

With eggs carefully taken and fertilized, and clear water of a temperature from 41° to 47° F., it is possible to hatch from 70 to 85 per cent of the eggs, but when the temperature gets below 38° the percentage of fry hatched is only from 25 to 50, and the average for the season is thus greatly reduced. The number of fry hatched is determined by deducting the losses shown on the hatching-cards from the number of eggs originally in the box. One liquid ounce is estimated to contain 10,524 eggs.

CLEANING THE EGGS.

Owing to the accumulation of sediment and other foreign matters in the hatching-boxes, it is necessary to clean the eggs daily, running the sound eggs from one box to another through a slot, the dead eggs being left behind. The slots in the partitions dividing the hatching compartments correspond with similar slots in the boxes; they are 3 to 3½ inches long and 1½ inches deep, and are placed 3 inches from the front of the compartments. To begin the cleaning of a given row of boxes, a glass slip is fitted into the slot between the second and third boxes, the first box being left empty for the purpose of receiving the cleaned eggs from the second box. A wooden plug is then put in the current hole at the back of the second box, and the siphon cap is removed from the waste-pipe; this allows the box to fill with water, and the eggs, undisturbed by the current, rise to the surface. The water is allowed to enter the first box and to gradually fill it to the level of the waste-pipe, and is then turned off. A plug is next put in the waste-pipe of the box containing the eggs; the water rises till it reaches the slot, and then runs over into the first box, carrying the good eggs with it, while the dead eggs remain in the box. The regular water circulation is then established in the first box.

The inner box from which the good eggs have been removed is taken out and the remaining eggs are washed into one end and poured into

a glass graduate. The dead eggs quickly sink and the quantity, in ounces, is noted on a card attached to each box. If there are any good eggs in the glass they are saved; the spoiled eggs are thrown into the waste-trough. Both the inner box and the trough in which it rests are thoroughly washed and sponged after each change.

When the inner box is replaced it is made ready for the eggs to be transferred from the third box, and the same method is pursued until all the boxes have been cleaned. Eggs recently taken, being on the surface, run over very quickly, 5 or 10 minutes usually sufficing for the transfer of a box of 400,000 eggs; but when eggs become heavier, as a result of development, the cleaning takes much longer, as it is then necessary to run them into the lower part of the box (as in removing dead eggs) and to dip them out, care being taken to keep the lower end of the box in the water while manipulating them. As the loss of eggs has ceased by the time they reach this stage, everything in the box may be dipped over, and with care no damage is done the eggs.

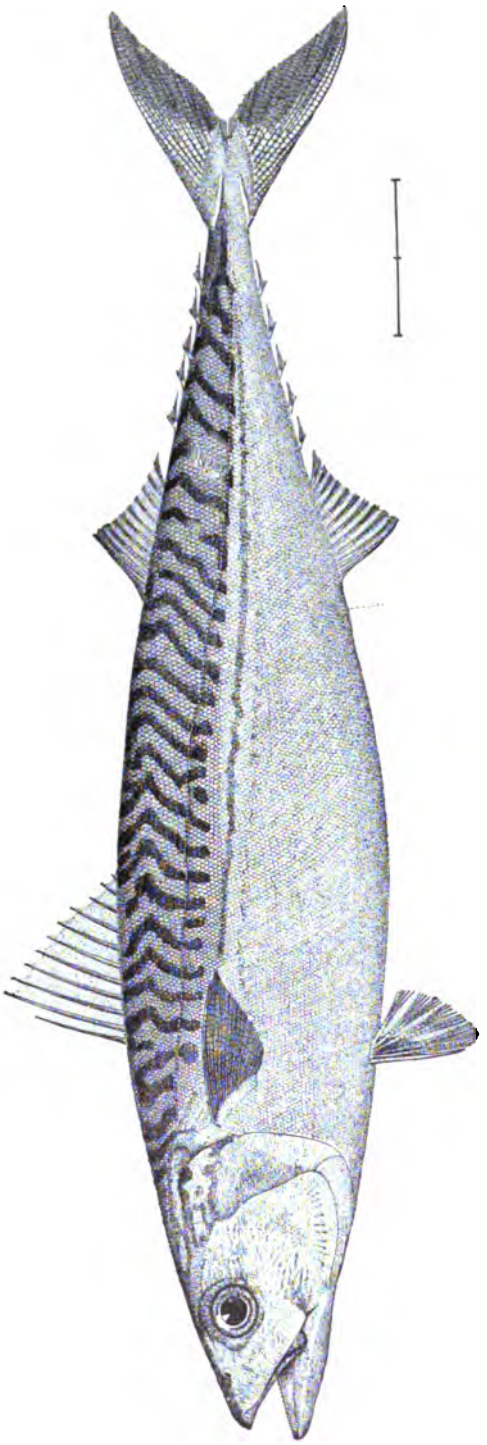
THE FRY.

When the fry first hatch they are much curved in shape and show but little vigor. If the water is comparatively warm they rapidly straighten out and become stronger. At this stage they float at the surface, except when forced about by the current. As they get older they frequent the upper water less and if kept in the boxes till the mouth begins to functionate most of them remain on or near the bottom.

As soon as the first fry in a given box make their appearance the eggs are all run over for the last time. As the fry are comparatively delicate they are handled as little as possible and with great care.

The fry are planted as soon as practicable. If all the eggs of a given lot have not hatched it is better to plant them with the fry rather than hold the latter until incubation is complete, for the boxes soon become foul from the accumulation of eggshells and the eggs will hatch in a very short time, especially as the water on the spawning-grounds is usually 3 or 4 degrees warmer than the water in the hatchery.

When the fry are to be removed from the boxes, preparatory to planting, a plug is put in the current hole at the back of the box, and in a short time most of them will come to the surface. They are then dipped out and put in transportation cans. About 200,000 fry may be safely carried in a 10-gallon can. Deposits are usually made on the natural spawning-grounds.



SCOMBER SCOMBRUS. *Common Mackerel.*

THE MACKEREL.

DESCRIPTION, SIZE, ETC.

The genus *Scomber*, of which the mackerel (*Scomber scombrus*) is the leading representative, is distinguished from related genera of scombroid fishes of the Atlantic coast (*Auxis*, the frigate mackerels; *Gymnosarda*, the little tunnies; *Thunnus*, the great tunnies; *Sarda*, the bonitos, and *Scomberomorus*, the Spanish mackerels and kingfish) by the small size of the species, by the absence of a median keel on each side of the caudal peduncle, by a short spinous dorsal fin having 9 to 12 spines, by the pattern of coloration, and by a number of other characters.

The body of the mackerel is fusiform and but little compressed laterally. The standard length is 3½ times the depth. The caudal peduncle is slender, with a small keel on either side. One-third of the total length without tail consists of the head. The eye is rather small, its diameter being only one-fifth the length of the head. The mouth is large and armed with a row of small slender teeth in each jaw. There are two dorsal fins, the anterior containing 11 spines and the posterior 12 rays, following which are 5 finlets; the formula of the anal fin is 1 spine, 11 rays, and 5 finlets. The scales are very small, numbering several hundred along the lateral line. The color is dark blue above and white below. About 35 dark wavy vertical streaks mark the back.

The common mackerel closely resembles the other species of the same genus found on both the Atlantic and Pacific coasts, namely, the bull's-eye, chub, or thimble-eye mackerel (*S. colias*), but is separated from it by the absence of the air-bladder, more dorsal spines, smaller eye, and somewhat different markings.

The length of the full-grown mackerel is 17 or 18 inches, but fish a little over 20 inches long, and weighing upward of 3¼ or 4 pounds, are occasionally taken. The average length of the market catch is about 12 inches. Such a fish weighs from three-fourths of a pound to a pound.

Small mackerel are known among the fishermen by several names, such as "spikes," "blinkers," and "tinkers." Spikes are the smallest caught by the commercial fishermen; they are 5 or 6 inches long and are 5 to 7 months old. Tinkers are under 9 inches in length and are supposed to be about two years old. Blinkers are intermediate in size and age. Maturity is probably attained in the fourth year.

DISTRIBUTION, MOVEMENTS, ABUNDANCE, AND SPAWNING.

This species inhabits the North Atlantic Ocean. On the American coast its range is from Cape Hatteras to the Straits of Belle Isle. On the European coast the fish is found from northern Norway, in latitude

71°, to the Mediterranean and Adriatic. It is not recorded from the West Indies, Bermudas, Gulf of Mexico, South America, or Africa.

On the east coast of North America mackerel first appear in the spring off Cape Hatteras and subsequently reach the shores of the Middle and New England States and the British possessions, migrating in from the sea from a southerly or southeasterly direction. Certain bodies of fish seek the New England shore, while others first strike the shore of Nova Scotia and follow it into the Gulf of St. Lawrence. They leave the coast in the same way in fall and early winter.

The mackerel is a wandering fish. Its movements when in the coast waters are undoubtedly regulated by external causes not yet clearly understood, but food, temperature of water, and reproduction are potent factors.

The mackerel is one of the most abundant fishes found on the Atlantic coast. It goes in schools, often of immense extent. The testimony of reliable fishermen relative to the size of schools observed often seems incredible; thus one school seen in the South Channel in 1848 was half a mile wide and at least 20 miles long. Another school noticed off Block Island in 1877 was estimated to contain 1,000,000 barrels. The schools swim at the surface or at varying depths beneath the surface, and present a comparatively broad front.

From the earliest times, there have been periods of scarcity of mackerel alternating with seasons of abundance. As early as 1670 the Colony of Massachusetts enacted laws for the preservation of mackerel. Since 1885 there has been the most noteworthy and prolonged scarcity of the fish of which there is any record. The New England catch in 1885 was 330,000 barrels, and in the 8 years ending in 1885 averaged 309,000 barrels; in 1886 it fell to 80,000 barrels, and in the succeeding 10 years aggregated only 481,000 barrels; was several times below 25,000 barrels, and never exceeded 89,000 barrels. The yield in 1898 was 5,769,000 pounds, fresh, valued at $307,000, and 15,500 barrels, salted, worth $179,000.

The spawning season on the east coast of North America includes the months of May, June, and July, June probably being the principal month. The spawning-grounds are in rather deep water and extend along the entire coast from Long Island to the Gulf of St. Lawrence. Most of the bays and sounds of the New England coast are important spawning-grounds, as is also the Gulf of St. Lawrence. Prior to spawning and for several weeks thereafter the mackerel are lean and poor and never make No. 1 fish when salted.

FOOD AND ENEMIES.

The mackerel feeds on a large variety of small animals, and is in turn eaten by a number of fishes, birds, cetaceans, etc. The relations existing between the presence of favorite food and of enemies on one hand and of mackerel on the other are fully appreciated by the commercial fishermen, who are often guided in their search for fish by the appearance of mackerel food in abundance or of their well-known

enemies. The presence of food is frequently shown by flocks of birds, especially phalaropes, which are called "mackerel geese."

The principal food objects of the mackerel are small crustaceans; copepods predominate, but shrimps of various kinds, young crabs, etc., are also important. One of the surface-swimming copepods, known as "red feed," "cayenne," etc., is a very favorite food; when mackerel have been feeding freely on it, they spoil very quickly after being caught, owing to their sides rotting or "burning." Fish constitute a rather important part of the mackerel's diet; herring, anchovy, sand launce, silversides, menhaden, and many other small fishes are eaten.

Among fishes, sharks are, perhaps, the most destructive enemies; mackerel sharks and dogfish are known to prey on the mackerel, driving and scattering the schools. Other fish enemies are bluefish and cod. Porpoises and whales are often seen feeding on the mackerel schools. Large squids do great damage to small mackerel. Among birds, the gannet is especially destructive.

THE MACKEREL FISHERY.

The mackerel is one of the best and most valuable food-fishes of the Atlantic Ocean. It is the object of important fisheries in Norway, Ireland, and Great Britain, and is extensively taken in the United States and the British provinces of North America. The fishery is prosecuted with vessels using purse seines, gill nets, and lines, much the largest part of the catch being taken in seines. In the boat fishery, lines and nets are employed. Stationary appliances, such as pound nets, trap nets, and weirs, also secure considerable quantities of mackerel.

In the United States the vessel fishery is carried on chiefly from Gloucester, Mass. The vessels sail south in early spring, and fall in with the fish when they first appear off the coast of the Southern and Middle States, the catch being landed fresh in New York and Philadelphia. The fleet next seeks the fish on the southern shore of Nova Scotia and follows the school north to the Gulf of St. Lawrence. During the summer some of the vessels enter the gulf, but most of them cruise on the New England shore, where most of the fall fishing is also done. Some of the finest fishing vessels of the United States are engaged in this fishery. In recent years the fleet has numbered only 150 to 225 sail, but formerly nearly 1,000 vessels were at times employed in this branch.

The shore and boat fishing is carried on from New Jersey to Maine. The fish thus caught are as a rule sold in a fresh condition.

The fishery is much less productive than formerly, and during the past ten years has not as a rule been profitable, although each year a few vessels make good catches and yield very satisfactory returns, owing to the high price of fish. The local fishing does not supply the home demand, and large quantities of fresh and salt mackerel are annually imported from Norway, Ireland, and the British provinces.

ARTIFICIAL PROPAGATION.

The artificial propagation of mackerel was more extensively prosecuted in 1896 than in any previous year. The long-continued scarcity of mackerel on the Atlantic coast of the United States seemed to warrant some efforts on the part of the Government to increase the supply by artificial means. The limitations of mackerel culture depend on the erratic movements of the fish in a given season or on a given part of the coast and the difficulty of securing healthy eggs in large quantities from fish taken by the commercial fishermen. During the summer of 1896, 24,000,000 mackerel eggs were collected. The work was largely experimental and only a small percentage of fry was hatched, but the outlook is good for a great expansion of mackerel propagation.

The egg of the mackerel is one of the smallest dealt with by the fish-culturist, being only $\frac{1}{24}$ inch in diameter. Being provided with a large oil-globule, it floats at the surface, like the eggs of many other marine fishes. Within 48 hours after fertilization it generally begins to sink, remains in suspension a short while, and then falls to the bottom, where it remains until hatching ensues.

Owing to the inability to retain mackerel in ponds or live-cars pending the ripening of the eggs, as is done with the cod, it is necessary to depend for the egg supply on the nets of the fishermen. The eggs collected at Woods Hole are secured from fish captured in pound nets near Chatham and at other points on the southern Massachusetts coast; at Gloucester traps in the vicinity furnish the eggs. As the nets are usually hauled only once or twice a day, the fish have often been caught for many hours, and the tender eggs have undergone considerable loss of vitality; the quality of the eggs seems to have a direct relation to the length of time the fish have been in the nets.

One of the most favorable grounds for collecting mackerel spawn is Casco Bay, on the coast of Maine. Mackerel are taken chiefly in drag nets set about 4 o'clock p. m., and hauled from 9 o'clock p. m. to daylight. Eggs from fish caught in the first hauls of the nets are of much better quality than those taken in the last lifts.

In collecting eggs from pound nets the spawn-takers accompany the fishermen when they visit their nets and overhaul the mackerel as they are taken into the boats. The collection of eggs from the drag-net fishermen requires the spawn-takers to remain on the fishing-grounds from early in the afternoon until the next morning.

There is nothing peculiar in the methods of stripping the fish, mixing the eggs and milt, and transferring the eggs from the field to the hatchery. Although both the wet and the dry methods of fertilization have been practiced, the latter apparently gives better results. The average number of eggs taken from a fish is probably about 40,000. Three mackerel, stripped at Woods Hole in 1893, yielded 434,500 ripe eggs, an average of 144,833 eggs. As many as 546,000 eggs have been taken from a $1\frac{1}{8}$-pound fish, and the largest fish probably yield fully 1,000,000

eggs. The largest number of eggs taken from one fish in Casco Bay in 1897 was 200,000.

From the field the fertilized eggs are conveyed to the station in jars, as described in the chapter on cod propagation. For short shipments they may be transported in buckets or cans.

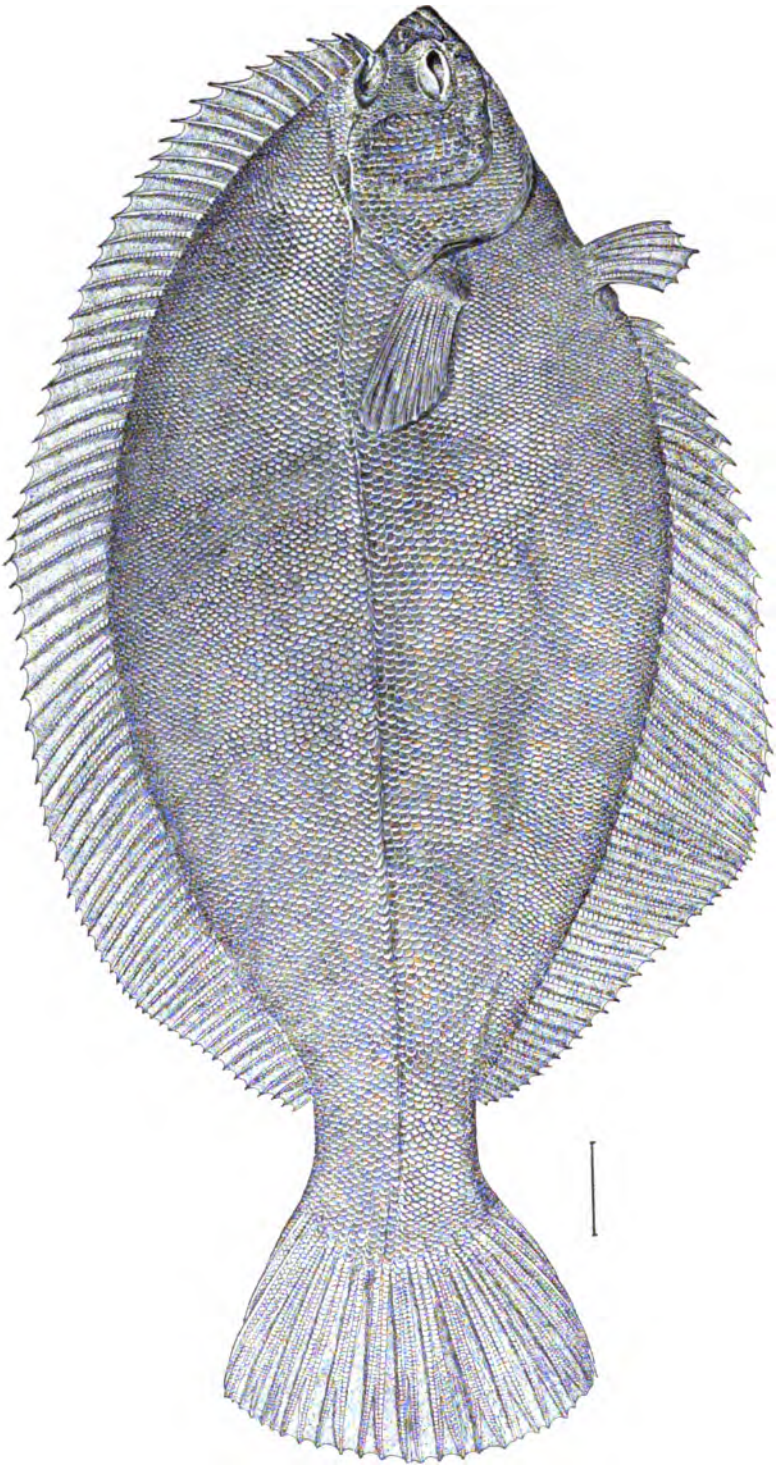
Mackerel eggs may be artificially incubated in a variety of ways. In 1896 three forms of apparatus were employed for comparative purposes. These were (1) the McDonald hatching-jar, with the water supplied through the long central tube and discharged through a cheese-cloth top; (2) the Chester jar, and (3) the automatic tidal-box; the latter gave the best results.

Owing to the very small size of the eggs, from 200,000 to 225,000 may be placed in a Chester jar and 450,000 or more in a tidal box 20 by 11 inches. The eggs are manipulated in about the same way that cod eggs are, but, owing to the short period of incubation, require very little handling.

For reasons not yet definitely determined, but apparently connected with the condition of the eggs rather than the methods of hatching, mackerel ova are liable to exceedingly large mortality during incubation. While as many as 75 per cent of certain small lots of eggs have produced fry, less than 1 per cent of most of the eggs hatch.

The period of incubation at a mean water-temperature of 58° is about 5 days. In 48 hours after impregnation the embryo is discernible, and in 68 hours its development is far advanced. The critical period seems to be the end of the third day, when a large part of the eggs die.

The fry are planted within 24 hours of hatching. They are taken to the natural spawning-grounds in regular transportation cans and liberated below the surface of the water.



PSEUDOPLEURONECTES AMERICANUS. *Flatfish, or Winter Flounder.*

THE FLATFISH, OR WINTER FLOUNDER.

The body of the flatfish (*Pseudopleuronectes americanus*) is regularly elliptical. The eyes and color are on the right side. The upper side of the head is covered with imbricated ctenoid scales similar to those of the body; the blind side of the head is nearly naked. The teeth are close-set, incisor-like, and form a continuous cutting edge; the right side of each jaw is toothless. The length of the head is contained 4 times in the length of the body and the depth 2¼ times in the body length. The dorsal fin contains 65 rays and the anal fin 48 rays. The lateral line, which is nearly straight, has 83 scales. The color above is dark rusty-brown, either plain or mottled with darker; the young are olive-brown, spotted with reddish; the under parts are white.

This species has a comparatively small mouth, and feeds chiefly on small shells, crabs, and other bottom animals. It is found on sandy, muddy, or rocky bottoms, and seems to prefer sheltered coves and bays. Its coastwise and bathic movements are limited. It is one of the most abundant flounders of the Atlantic coast, being especially numerous in southern New England and New York. It ranges as far north as Labrador and as far south as the Carolinas, but is not present in noteworthy quantities south of New Jersey. It does not attain a large size, the usual length being only 12 to 15 inches and the weight about 1½ pounds. Very rarely examples are taken over 20 inches long, weighing as much as 5 pounds.

The winter flounder is exceedingly prolific, over a million eggs being laid by a large fish. Along the coast of the southern New England and Middle Atlantic States the spawning season is from February to April. By August the young fish, having attained a length of 1 or 2 inches, are found in shallow water along sandy shores. The species is obtained principally during the winter and spring months, and large quantities are sent to the markets, where it sells readily at good prices. The flesh is white, firm, and of excellent flavor. Next to the halibut and the summer flounder, or plaice (*Paralichthys dentatus*), this is the most important flatfish of the Atlantic coast.

The winter flounder has been more extensively propagated than any other species of *Pleuronectidæ*, owing to the facility with which its eggs are obtained at Woods Hole, where its propagation fills in the time between the taking of cod eggs on one hand and of lobster eggs on the other, slightly overlapping the ending of the former and the beginning of the latter. The work covers that part of the year when the most

inclement and changeable weather occurs, and is necessarily somewhat limited in extent by uncontrollable physical and other conditions.

During the fiscal year 1895–96, the collections of flatfish eggs numbered 11,008,000, which yielded 8,472,000 fry; in the year 1896–97 84,591,000 eggs were taken, from which 64,095,000 fry were hatched.

The flatfish from which eggs are obtained are very plentiful during February in the Woods Hole region, being found on sandy or hard clay bottom, and taken in fyke nets set in water from 6 to 14 feet deep. As many as 60 to 70 fish are sometimes taken at one lift of a fyke net, but as a rule not more than two or three of this number are gravid fish. These nets are usually some distance from the station, and the fish are carried to the hatchery in transportation cans, six or eight being put in one can. In some cases this trip is made by water in a sail or row boat, while at other times it is made overland by team. The fish are often carried 10 or 12 miles without change of water and without apparent injury. A few are caught while the water temperature is as low as 33° F., but they are more numerous after the temperature reaches 34° or 35° F. On arriving at the station the fish are put into wooden tanks supplied with constantly changing water, and here they are held until ripe. It is customary to put both males and females in the same box or tank. The fish are examined daily and the eggs are taken from all which are found to have ripened, the stripped or spent fish being released.

The eggs of the flatfish are quite small, there being 30 in a linear inch. Unlike the eggs of the cod, haddock, mackerel, and other marine fishes, they do not float, but sink to the bottom of the vessel in which they are held. They are not so heavy as those of the lobster, and a slight current causes them to rise and carries them to a point where there is still water, when they again go to the bottom. When first deposited, the eggs are very adhesive and stick together in one mass or in clusters of different sizes. This adhesiveness is overcome, in a measure, by thoroughly washing them, and, as this force gradually weakens as the eggs become older, usually nearly all the eggs are separate when they begin to hatch. The use of dry powdered starch is very effective for this purpose; this mixes readily with the salt water and admirably overcomes the glutinosity of the eggs. Its action is purely mechanical.

In stripping, it is customary to fill a Chester jar with water and place inside the jar a bag made of cheese-cloth, into which the eggs are allowed to fall. The fish is grasped by the head with the left hand, the mouth being in the palm of the hand, and the edge on which the vent is located turned from the spawn-taker. The right grasps the fish near the tail, and as it is moved with gentle pressure toward the vent, at the same time that the left thumb is moving crosswise and exerting similar pressure, the eggs are extruded. The milt is then expressed in the same way; the eggs are stirred slightly with the hand to thoroughly mix them with the milt, and after allowing a short time for the action

of the milt they are cleaned and the superfluous milt washed off by introducing a gentle stream of water into the bag and rolling the eggs from side to side.

It frequently happens that fish held in tanks to mature deposit their eggs during the night. In such cases the eggs are found on the bottom of the tank the next morning. They are usually in clusters and when examined with the microscope it will be found that practically every egg is fertilized.

After the eggs have been taken and fertilized the number is calculated by measuring in a glass graduate and computing 48,726 eggs to the liquid ounce. The average number of eggs is about 500,000 to a fish. On March 6, 1897, 30 ounces, or 1,462,000 eggs, were taken from a fish 20 inches long and 11 inches wide, its weight being 3½ pounds after the eggs were taken.

Flatfish eggs may be hatched in several kinds of apparatus, but the Chester jar is most used, in combination with the McDonald tidal box employed in incubating cod eggs. From 400,000 to 500,000 eggs are usually placed in each jar. The top of the jar is covered with cheese-cloth held in place by rubber bands. The jar is then inverted and placed in a tidal box. The usual complement of each box is 2 jars. A wooden frame of 1-inch strips is placed lengthwise on the bottom of the box for the jars to rest on, so as to raise them and allow the free circulation of the water. A hole in the bottom of the jar allows the air to pass in and out as the water inside rises and falls. The inner compartment, with a bottom of cheese-cloth, used in cod-hatching is omitted.

As in using the jars the eggs are generally on the bottom all the time, the experiment has been tried of employing the McDonald box with the automatic current in order to keep the eggs in circulation. It having been found that the current commonly used for cod eggs caused the eggs to pile up in the end nearest the outlet, a stream was introduced into each end of the box and the water was allowed to escape in all directions through a perforated nozzle; the water was kept about 3 inches deep in the bottom of the box by using a quantity sufficient to prevent the breaking of the siphon. By this means a constant current is formed, the eggs develop nicely, and the fry hatch, but the current necessary to keep the eggs in circulation is strong enough to kill the fry by forcing them against the sides of the box. This experiment is therefore not considered a success.

The period of incubation when the mean water temperature is 37° or 38° F. is 17 or 18 days.

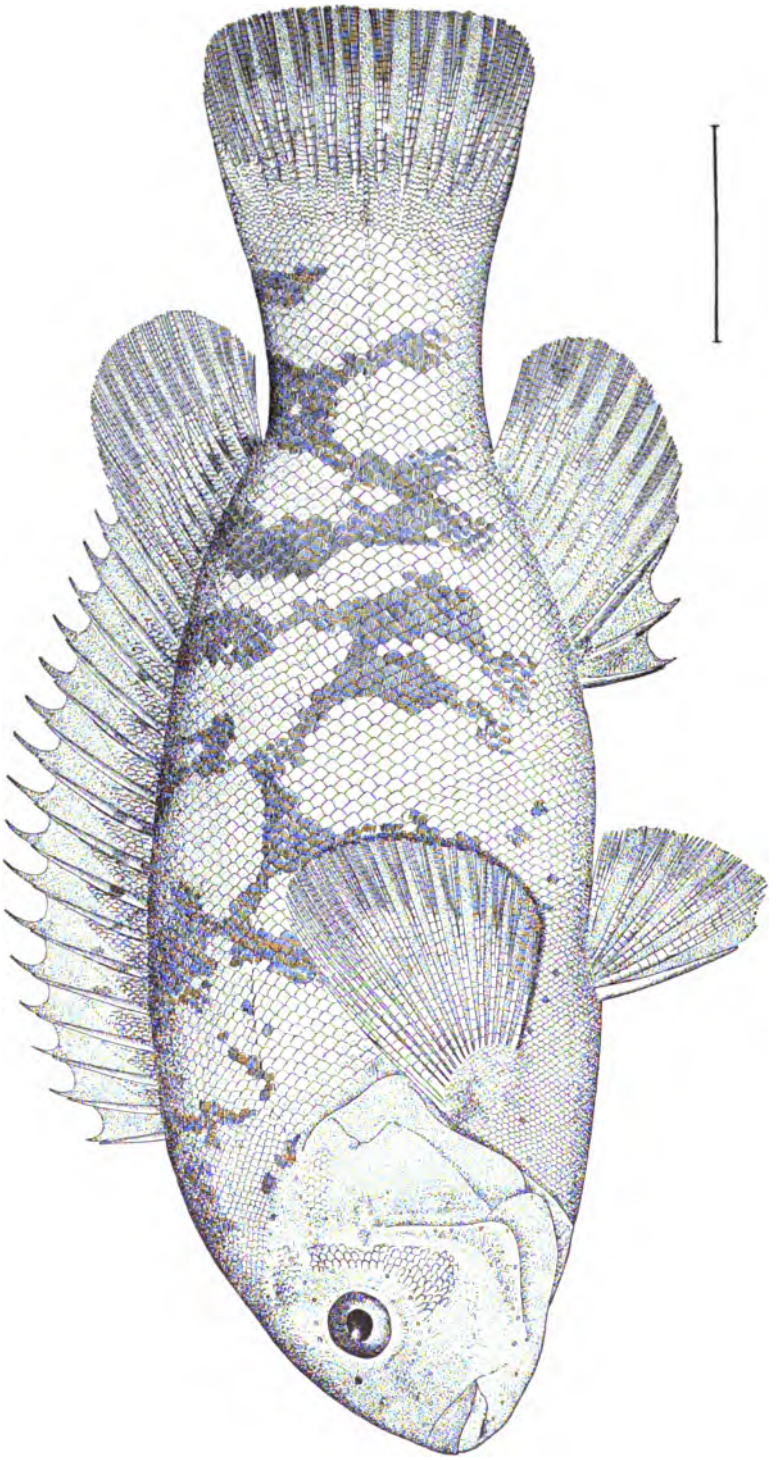
The fry of the flatfish, although much smaller than those of the cod, are much more lively, and are straightened out when first hatched. Unlike the young cod, they do not float on the surface, but are scattered through the water from top to bottom, many being seen among the eggs on the bottom of the jars. Unlike the adults, the flatfish fry

swim with the body upright, as young fish of other families do, and when first hatched the eyes are on opposite sides of the head. At the age of about three months, however, one of the eyes will have moved to the other side of the head, to conform with the change of the body in swimming from an upright to a flat position. The position constantly assumed by the very young fry is peculiar, the long axis of the body being vertical, with the head upward. This is owing to a large oil-globule in the anterior part of the yolk-sac.

The fry are quite hardy and stand transportation very well. They have been kept three weeks without change of water in a bottle hanging in a box of running water to maintain an even temperature in the bottle. In planting the fry, which is done in one or two days after hatching, they are put into the transportation cans commonly used for such purposes and taken in a boat to localities in which the brood fish are found. The cans are put overboard and sunk until the mouth is submerged, when the contents are gently turned out. For a trip of not more than two or three hours' duration, with water temperature about 38° F., from 400,000 to 500,000 fry may be safely carried in a 10-gallon can.

THE SAND-DAB AND FOUR-SPOTTED FLOUNDER.

Besides the flatfish or winter flounder, two other flounders have been artificially hatched, on a small scale, at Woods Hole; these are the sand-dab (*Bothus maculatus*) and the four-spotted flounder (*Paralichthys oblongus*). The eggs of both fish are buoyant, and deposited in May. Those of the former are $\frac{1}{24}$ inch in diameter, and of the latter $\frac{1}{26}$ inch. The period of incubation, at a temperature varying from 51° to 54° F., is about 8 days.



TAUTOGA ONITIS. *Tautog.*

MISCELLANEOUS MARINE FISHES.

In addition to the salt-water fishes previously considered, a number of others have been artificially propagated by the U. S. Fish Commission. With some of these the fish-cultural work has been rather extensive; with others, hardly more than experimental. Among those to which most attention has been given are tautog, Spanish mackerel, pollock, and haddock. Others that have come in for a share of either practical or experimental work are sea herring, scup, sea bass, squeteague, cunner, sheepshead, and several flounders.

The same methods of culture mentioned hereafter in connection with tautog are applicable in general to scup, sea bass, squeteague, and other species having floating eggs.

THE TAUTOG.

The tautog (*Tautoga onitis*) is a strongly marked species. It belongs to a family (*Labridæ*, or the wrasses) characterized in part by one dorsal fin, thoracic ventral fins, double nostrils, thick lips, and strong teeth in the jaws. The tautog has an elongated body and a large head with a convex profile. The rather small mouth is armed with strong conical teeth in two series. The eye is small and placed high on the side of the head. The body is covered with small scales, in about 60 transverse rows and 40 longitudinal series. The head is destitute of scales, with the exception of a small patch behind the eye. The dorsal fin is long and low, with 16 strong spines and 10 soft rays. The anal fin contains 3 spines and 8 rays. The body length is $3\frac{1}{4}$ or $3\frac{1}{2}$ times that of head and $2\frac{2}{3}$ or 3 times the depth. The gillrakers are short, feeble, and number only 9. The color of adults is almost uniformly blackish or greenish; the young are marked by dark irregular crossbars on a pale brownish background; chin, white; iris, bright green.

The tautog is of considerable importance in certain parts of its range. It is found from Maine to South Carolina, but is most abundant in Massachusetts, Rhode Island, and New York. It is one of the best-known shore fishes of the east coast, and goes by a variety of names, among which are blackfish, chub, oyster-fish, and moll, besides the most generally used name of tautog.

The tautog inhabits principally rocky bottom, where it hides in crevices, often with its body in an apparently very unnatural position. It is quite susceptible to changes in temperature, and during winter enters into a state of hibernation in the more northern parts of its range. Its coastwise movements are very limited. Its sharp strong teeth enable it to consume mollusks and crustaceans, which are its chief food; it also eats sand-dollars, worms, and other animals.

The tautog is taken for market in considerable numbers by means of lines and traps. It bites quite readily and is a favorite with anglers. Its average weight as caught for sale is not more than 2 or 3 pounds, but tautog weighing from 6 to 15 pounds are not rare. The maximum weight is about 22½ pounds; such a specimen from New York, 36½ inches long, is preserved in the U. S. National Museum. The annual commercial catch of tautog is about 1,000,000 pounds, valued at $25,000. Most of the yield is from Massachusetts, Rhode Island, and New Jersey.

The spawning season on the southern New England coast extends from April to August, although June appears to be the principal month. The young are very abundant along the shores in the fall.

The artificial propagation of tautog was experimentally undertaken at Woods Hole in 1886. In 1896, 31,431,000 eggs were taken in June; from these 17,575,000 fry were hatched and planted in neighboring waters.

Tautog from which eggs for hatching are taken are obtained from nets or from line fishermen near the station and transferred to live-cars. When first brought in they seldom yield any eggs, but in 2 to 6 hours they may be stripped of a part of their eggs. The eggs taken after fish are held more than 6 hours are usually of no value, and those obtained from fish retained one night are invariably worthless.

The tautog is very prolific. In 1896 a 9¾-pound fish yielded 1,142,600 eggs, and it was estimated that the ovaries contained fully as many more eggs that were not yet mature. The average number of eggs per fish is from 150,000 to 200,000.

The eggs of the tautog are about $\frac{1}{26}$ inch in diameter. They are buoyant, like those of the mackerel, and are susceptible of the same method of hatching. When placed in the automatic tidal box, they hatch in about 5 days, with the water temperature at 69° F., and in 2 or 3 days with the temperature at 71°.

The newly hatched fry are transparent and exceedingly small, the length being only $\frac{1}{12}$ inch. They are quite hardy and stand transportation well. They are planted shortly after hatching.

THE SPANISH MACKEREL.

The Spanish mackerel (*Scomberomorus maculatus*) is the best-known fish of the genus and the only one that has received the attention of fish-culturists. From the other species of *Scomberomorus* found on the eastern United States coast (*S. regalis*, the kingfish, and *S. cavalla*, the cero) this fish is, in part, distinguished by its smaller size and by the insertion of the soft dorsal fin in advance of the anal. The body is long, the head small and pointed, the mouth large and armed with prominent teeth. The anterior dorsal fin has 17 spines, the soft dorsal has 18 rays. The anal fin has 2 spines and 17 rays. Behind both the dorsal and anal fins are 9 small finlets. The lateral line is wavy and has about 175 pores. The general color is silvery, dark-bluish above and whitish below. The sides have numerous rounded yellowish spots.

This fish is widely distributed, being found on both coasts of North America. On the west coast it does not enter United States waters, but on the Atlantic seaboard it ranges from Texas to Massachusetts. It is especially abundant in the Gulf of Mexico, among the Florida keys, in Chesapeake Bay, and on the coast of the Middle Altantic States.

Its maximum weight is about 9 pounds. Many weighing only 1 or 1½ pounds are caught for market, and the average is less than 3 pounds.

The Spanish mackerel is one of the choicest food-fishes of American waters; in popular estimation it is scarcely surpassed by any marine species except the pompano. It is caught throughout its range on the east coast with gill nets, seines, pound nets, and lines. The principal fishing is on the west coast of Florida, on the Louisiana coast, in the lower part of Chesapeake Bay, and on the coasts of New Jersey and New York. The approximate annual value of the catch at present is $112,000, which represents 1,700,000 pounds. In 1880 the output was 1,887,000 pounds, having a value of $132,000. The yield in the Middle States is much less than formerly, while in the Gulf States it has increased.

The fish spawns throughout its entire range on the United States coast. The spawning season is quite prolonged, extending from April in the Carolinas to September in New York, and in a given locality continues from six to ten weeks. All of the eggs in the ovaries of a given fish do not mature at one time; eggs in all stages of development may be found, suggesting a comparatively long spawning season for individual fish as well as for the species as a whole. The eggs, when laid, float at the surface, where they are driven about by wind and tide. Doubtless a large percentage of the eggs do not hatch, through failure of fertilization and by being stranded. The eggs are very small, their diameter being only $\frac{1}{28}$ to $\frac{1}{22}$ of an inch.

The artificial impregnation and hatching of Spanish mackerel eggs were first accomplished in 1880, since which time the propagation of the fish has been taken up on a number of occasions, although the work in any one season has been comparatively limited.

The serious diminution in the supply of this species in certain sections seems to call for its artificial cultivation whenever it can be taken up without detriment to the propagation of other more or equally important fish.

In the work of artificially propagating this fish recourse has been had to the nets of commercial fishermen for the supply of spawn and milt. Chesapeake Bay has been the seat of the principal operations, which have been conducted by the steamer *Fish Hawk*. The catch of Spanish mackerel in this bay in pound nets and other appliances is very large, and the facilities for fish-cultural work of this character are doubtless superior to those of any other section, with the possible exception of the west coast of Florida.

The necessity for depending on the fishermen for the supply of eggs is somewhat detrimental to the best results and prevents extensive work, although the owners of fishing apparatus heartily cooperate.

Owing to the fact that the fish appear to spawn mostly at night, when the pound nets are lifted in the morning the ripe eggs have in many cases been extruded before the spawn-taker could secure them. The injuries which the fish sustain while in the pound nets and during the hauling of the nets appear to seriously affect the eggs and cause the non-hatching of a comparatively large percentage. Undoubtedly better results may be obtained if a number of nets are fished exclusively for this purpose, insuring the careful removal of fish at the best times for taking and fertilizing the eggs.

The eggs are very delicate and susceptible to meteorological influences. Their development is markedly affected by water temperature and atmospheric conditions; electrical disturbances, as with other fish eggs, are injurious, but to what extent and in what way are not known. The largest number of ripe eggs thus far taken from a single specimen is 60,000, but the average is only 20,000.

The Chester jar, such as is used in hatching flatfish eggs, has been found the best apparatus for Spanish mackerel eggs. If the jars are kept clean and not overcrowded, a constant current of water does not seem to be essential; of a lot of 60,000 eggs in a jar of quiet water, 90 per cent hatched. The cod tidal-box is also adapted to this work.

In ordinary bay water having a density of 1.014 to 1.019, the eggs are buoyant and remain at the surface until hatching ensues; but in water of low specific gravity they sink and give unsatisfactory results. The period of incubation is very short. Under normal conditions eggs hatch in 20 to 30 hours, averaging 25 hours, at a temperature of 77° or 78°. The fry are planted soon after hatching.

HADDOCK, POLLOCK, AND OTHER GADIDÆ.

The methods of culture employed with the cod are applicable to other members of the cod family having buoyant eggs. The United States Fish Commission have frequently taken and hatched eggs of the pollock (*Pollachius virens*) and the haddock (*Melanogrammus æglifinus*). Both are important food-fishes, but much less valuable than the cod, and the collection of eggs has generally been only supplemental to cod work.

The pollock is found from New Jersey northward. It goes in large schools, which are often found at the surface, thus differing from the cod and haddock. The average weight is 9 or 10 pounds, and the maximum about 30 pounds. Fishing is chiefly done from small vessels and boats, and is most important in Massachusetts. The value of the annual catch is about $65,000. The pollock is an excellent food-fish in both a fresh and a salted condition.

The eggs of the pollock have at times been gathered in large numbers in the vicinity of Gloucester; during some seasons about 40,000,000 eggs have been taken. The eggs measure about $\frac{1}{22}$ inch in diameter. The pollock spawning season includes the months of October, November, and December. The fish from which eggs are obtained are taken

with nets and lines by commercial fishermen; the average number of eggs to a fish is from 200,000 to 250,000. The period of incubation is somewhat shorter than that of the cod, being 9 days at 43° and 6 days at 49°. About 5 days are required for the absorption of the yolk-sac.

The haddock ranges from Delaware northward, and is, as a rule, very abundant on the "banks" lying off the New England shore. In its habits it is similar to the cod, frequenting the same grounds and being caught at the same time. Its average weight is about 4 pounds and the maximum under 20 pounds. The fishery is very extensive in Massachusetts, most of the catch being landed fresh in Boston. The annual yield is about 50,000,000 pounds, worth $850,000.

The artificial propagation of haddock has been conducted chiefly at Gloucester, where as many as 30,000,000 eggs have been collected in a single season. The eggs are about $\frac{1}{17}$ inch in diameter, and are quite delicate and tender. The spawning time extends from January to June. The average production of eggs per fish is about 100,000.

The eggs are slightly glutinous and have a tendency to form into small lumps during hatching. At a mean temperature of 37° they hatch in 15 days, and at 41° in 13 days. The yolk-sac is absorbed in 10 days at a temperature of 41°.

The tomcod or frostfish (*Microgadus tomcod*) has been extensively propagated by the New York Fish Commission. It is a small but excellent food-fish, found along the Atlantic coast from New York to the Bay of Fundy. It is most abundant in early winter, when it approaches the shores and ascends streams for the purpose of spawning. It rarely exceeds 10 or 12 inches in length.

THE CUNNER.

The eggs of the cunner or chogset (*Ctenolabrus adspersus*) are of the same size and character as those of its near relation, the tautog, and are deposited during the same season. In water having a mean temperature of 56° F. they have been hatched in 5 days, in the tidal cod-jar. On account of the small size, great abundance, and comparatively little commercial value, the propagation of the cunner has not been regularly undertaken.

THE SCUP.

The scup (*Stenotomus chrysops*) is a rather important small food-fish found along the Atlantic coast from Cape Ann to South Carolina; it is most abundant in southern New England. It spawns in June. The eggs are $\frac{1}{26}$ inch in diameter and hatch in 4 days at a mean temperature of 62° F.

THE SEA BASS.

The eggs of the sea bass (*Centropristes striatus*) are of the same size as scup eggs, are deposited in June, and hatch in 5 days with the water temperature 59° or 60°. The sea bass is an important food-fish,

found from Massachusetts to Florida; it is taken in large quantities from New Jersey northward with lines and traps. It attains a weight of 5 pounds, but the average weight is only 1 or 1½ pounds.

THE SQUETEAGUES.

The squeteague or weakfish (*Cynoscion regalis*) is a prominent food-fish of the Atlantic and Gulf coasts, the northern limit of its range being in the vicinity of Cape Cod. It goes in immense schools and is taken in large quantities for market, in North Carolina, Chesapeake Bay, Delaware Bay, on the New Jersey and New York coasts, and in southern New England. It varies greatly in size; the average weight is under 5 pounds, but it has been known to attain a weight of 30 pounds. In the vicinity of Woods Hole this fish spawns in June. Its eggs are $\frac{1}{28}$ inch in diameter, and at an average temperature of 60° F. hatch in 2 days.

The spotted squeteague or "sea trout" (*Cynoscion nebulosum*) has also been propagated on a small scale. It is a valuable food-fish from Chesapeake Bay southward, being taken in largest quantities in Virginia, North Carolina, Florida, and the Gulf States. Its average weight is 2 pounds and its maximum 10 pounds. It spawns in bays and sounds in spring and summer, the time varying with the latitude. The eggs are buoyant, $\frac{1}{32}$ inch in diameter, and hatch in about 40 hours at a temperature of 77° F. This species has been artificially hatched on the southwest coast of Florida by the steamer *Fish Hawk*.

THE SHEEPSHEAD.

The sheepshead (*Archosargus probatocephalus*) is generally regarded as one of the best food-fishes of American waters. Its deep body, of a grayish color, marked by 8 transverse black bands, and its peculiarly shaped head, with mouth armed with prominent incisor teeth, make it readily recognized. It ranges from Cape Cod to Texas, but is most abundant from Chesapeake Bay southward. It attains a weight of over 20 pounds, but the average weight on the Atlantic coast is not over 7 or 8 pounds, and in the Gulf of Mexico scarcely exceeds 3 pounds. In southern waters the fish is a permanent resident, but in the northern part of its range it is found only during spring, summer, and autumn. The spawning season is from March to June, according to the locality.

The artificial hatching of the sheepshead has been undertaken on several occasions, but is not regularly prosecuted. The most extensive work was conducted by the *Fish Hawk* in March and April, 1889, when 23,400,000 eggs were taken in the vicinity of San Carlos Bay, on the southwest coast of Florida. These yielded 16,500,000 healthy fry, most of which were planted in local waters.

In capturing spawning fish on the Florida coast it was found that the best time to use the seine was just before sundown, as the flood tide was about to "make." The fish were then easily taken in large numbers. Seine hauls in the morning consisted only of male fish. Spawning

sheepshead swim in schools, and seem to prefer sandy beaches, along which they resort at a depth of 6 or 8 feet.

The sheepshead egg is very small, transparent, and of less specific gravity than sea water. The diameter is $\frac{1}{32}$ of an inch, and the number in a fluid ounce is about 50,000, or 1,600,000 in a quart.

The eggs are satisfactorily incubated in the tidal cod-jar, about 300,000 eggs being placed in each jar. The development is very rapid, and in the warm water of the Gulf (76° or 77° F.) the eggs hatch in 40 hours. The newly hatched fry are very small, but active and strong, and withstand considerable rough handling. They are planted when 72 to 80 hours old.

It is probably not practicable to carry on extensive sheepshead hatching north of Florida, although small quantities of eggs could doubtless be taken in North Carolina and Virginia.

THE SEA HERRING.

The sea herring (*Clupea harengus*) may be distinguished from other clupeoid fishes found in United States waters by the following characters: Body elongate and laterally compressed, the depth contained 4½ times in length; mouth at end of snout; lower jaw projecting, extending to beneath the middle of eye; roof of mouth with an ovate patch of small teeth; gillrakers long and slender, about 40 below the angle in adults, fewer in young; dorsal fin with 18 rays, inserted slightly behind middle of body; ventral fins beginning beneath middle of dorsal; anal fin with 17 rays; median line of belly with 28 weak spines or scutes in front of ventral fins and 13 behind fins; scales thin, easily detached, posterior edges rounded, 57 in lateral series; color bluish or bluish-green above, light-silvery below.

The sea herring exists in great abundance on both shores of the Atlantic Ocean north of the latitude of about 37° north. On the coast of North America it is not regularly abundant south of Cape Cod, but it is occasionally found as far south as Chesapeake Bay. In number of individuals this species is probably exceeded by no other fish. On the Pacific Coast a similar and almost equally abundant species (*Clupea pallasii*) is found from Alaska to Mexico.

There are no well-defined movements of the herring on the west shore of the Atlantic, if those induced by the spawning instinct are excepted. There was formerly a distinct shoreward migration, during the winter months, in the Bay of Fundy, but this run has not occurred for a number of years. In many places the herring, especially the smaller individuals, appear to be resident in the shore waters. The maximum length of this fish is about 17 inches, and the usual length of spawning fish on the United States coast is from 11 to 14 inches.

The herring subsists on minute invertebrates, chief among which are copepods, larval worms, and larval mollusks. In turn it is consumed in enormous quantities by cod, haddock, sharks, and many other fishes.

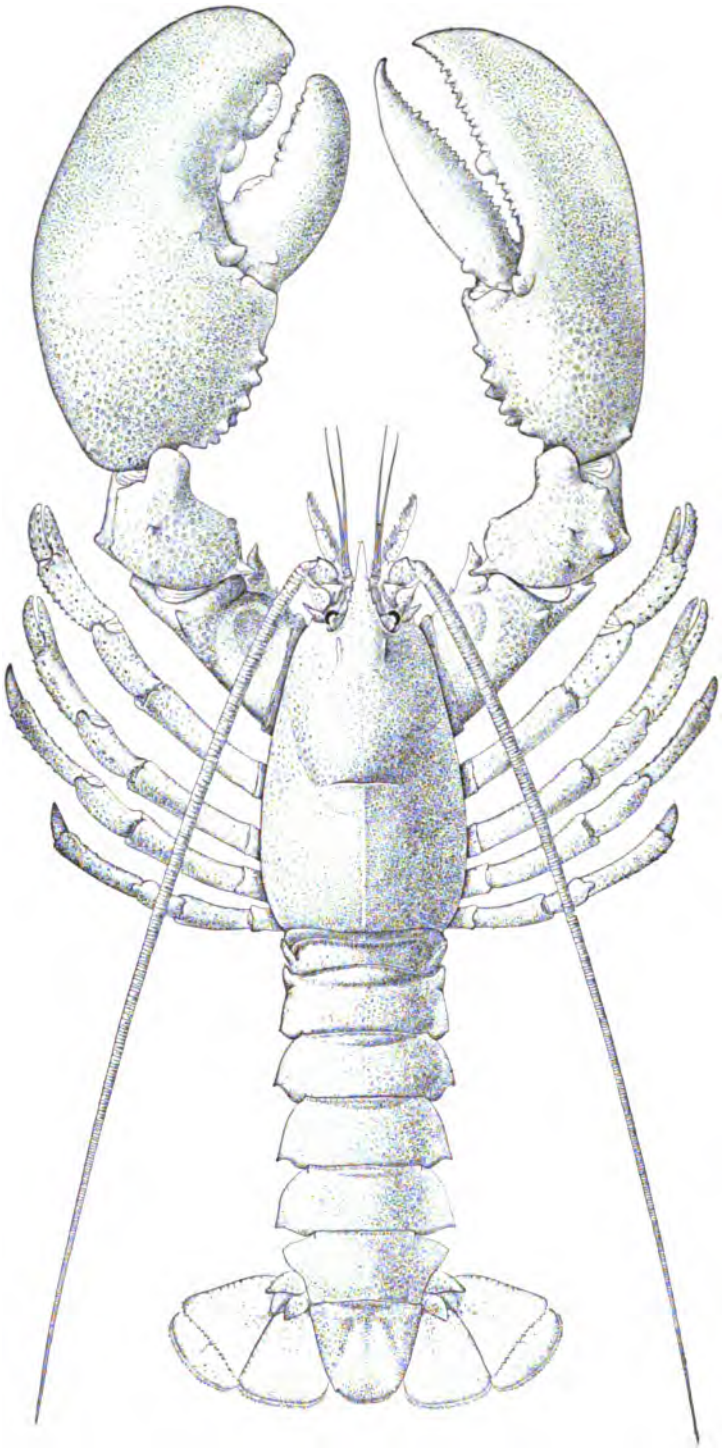
With respect to the time of spawning, the herring may be divided into two groups, one spawning in the spring, in April, May, and June, and the other between July and December. The spring spawning occurs entirely east of Eastport, Maine, and the fall spawning principally, but not entirely, west of that place. Probably the greatest spawning grounds south of the Gulf of St. Lawrence are at Grand Manan, where the eggs are deposited principally in July, August, and September. Thence the season becomes progressively later westward, on the coast of Maine occurring between September 1 and October 15; on the eastern coast of Massachusetts, between October 1 and November 1, and south of Cape Cod from October 15 to December 1.

The female of average size deposits between 20,000 and 47,000 eggs at a spawning, usually not far from 30,000. The eggs are deposited upon the bottom, and, being covered with a glutinous material which soon hardens in contact with the water, they become firmly attached to extraneous materials, to which they often adhere in masses as large as a walnut. The egg measures about $\frac{1}{20}$ inch in diameter, and is usually polyhedral from mutual pressure exerted by the eggs in masses.

The commercial value of the sea herring is almost incalculable. It is undoubtedly the most important of food-fishes, although in the United States it is surpassed in economic value by many marine and fresh-water species. Some time ago the annual yield of the world was estimated at 3,000,000,000 fish, weighing 1,500,000,000 pounds, the principal part of which was taken in Norway. In the New England States the annual catch is about 70,000,000 pounds, with a first value of $600,000.

The herring has been artificially propagated both in this country and in Europe, but owing to its great abundance the work has been only experimental. In the United States there has as yet been no permanent diminution of the supply that renders the cultivation of the species necessary, notwithstanding an extremely large fishery and the sacrifice of enormous quantities of very small fish. The first successful attempt to propagate this fish was in 1878, in Germany, when elaborate experiments were made. In the same year the artificial hatching of the species was accomplished by the U. S. Fish Commission. The eggs, owing to their cohesion into masses, showed a tendency to molding, but this difficulty could doubtless be obviated by the use of starch, as with other cohesive eggs.

Development takes place in water ranging in temperature between 33° and 55° F., the time of incubation varying from about forty days at the former temperature to eleven or twelve days at the latter. Sudden and extreme variation between the temperature limits mentioned had little or no effect except to retard or accelerate the hatching in accordance with the rule just mentioned. When water of a temperature lower than 33° F. was used many of the embryos were deformed. The degree of salinity of the water does not appear to exert much influence upon the hatching of the eggs.



HOMARUS AMERICANUS. *American Lobster.*

THE AMERICAN LOBSTER.

DESCRIPTION.

The lobster (*Homarus americanus*) belongs to that group of the crustacea called the Decapoda, because all of its members are provided with ten feet, more or less adapted for walking. To the Decapoda also belong the crabs and the shrimps, prawns, and crayfish. The crabs are less related to the lobster than the other forms mentioned, and may be readily distinguished from them by the relatively great breadth of the body and the small size of the abdomen or tail, which is doubled under the thorax to form the "apron." The lobsters, crayfish, shrimps, etc., are elongate forms with the tail or abdomen very large and extended more or less in the same horizontal plane with the anterior part of the body. The lobster and the crayfishes are somewhat closely related, but differ, among other characters, in the number and structure of the gills and in the relative size of the flat plate or scale which is attached at the base of the antennæ or long feelers. The Pacific Coast crayfishes have 18 gills, those east of the Rocky Mountains have 17, while the lobster has 20. The appendage of the antenna is large in the crayfishes, but very small in the lobster. Moreover, the crayfishes rarely exceed 5 or 6 inches in length, while the adult lobster is much larger, as seen in the markets, seldom measuring less than 9 or 10 inches. The spiny lobster, the "lobster" of the Pacific Coast, is readily distinguished from the crayfish and the common lobster by the total absence of great claws, by the greater length and stoutness of the antennæ, and by the presence of large, broad-based, spinous processes on the back.

The body of the lobster is divided into two distinct regions, the cephalothorax and abdomen. The former consists of the head and thorax fused into one united whole. That portion which would constitute the head, were it separate, bears the eyes, the two pairs of feelers, and the mouth, with the several pairs of modified limbs which surround that organ and assist in tearing up the food and passing it into the mouth. The thoracic portion of the cephalothorax is furnished with five pairs of stout limbs, the first pair bearing the great claws, which are rarely of the same size on the two sides, and the last four pairs being used in walking. From the fact that this portion of the body bears five pairs of appendages, it is assumed that it represents five fused segments.

The abdomen is narrower than the cephalothorax and is composed of six separate segments movable on one another. In the female the

first five pairs of abdominal appendages, known as swimmerets, are all similar and consist of a short basal piece and two terminal pieces side by side. The appendages of the sixth segment consist of the same arrangement of parts, but the pieces are broad and paddle-like, and, with the terminal plate attached to the last segment, constitute a powerful caudal paddle or tail. In the male the abdomen is narrower than in the female, and the first two pairs of swimmerets differ much from those which follow.

The color of the lobster is subject to great variation, but most frequently is dark bluish-green above, mottled with dark-green blotches; there is usually more or less red or vermilion on the appendages, especially on the tubercles, tips, and under side of the great claws and on the antennæ; the walking legs are light blue with reddish tips and tufts of hair. Occasionally specimens are found which are almost entirely red, and more frequently they are blue or bluish in general tone.

DISTRIBUTION AND ABUNDANCE.

The lobster is found from Labrador to Delaware, its range covering about 1,300 miles of coast line. Stragglers have been taken on the coasts of Virginia and North Carolina. While the bathic range is practically limited by the 100-fathom line, it is occasionally found long distances from land on the fishing-banks off the New England coast.

The lobster is most abundant in the northern part of its habitat. On the United States coast it is most numerous in Maine. In the provinces of Nova Scotia, New Brunswick, and Quebec, and also in Newfoundland it is extremely abundant.

MOVEMENTS.

The movements of the lobster are chiefly on and off shore. Such coastwise movements as characterize the mackerel, bluefish, and menhaden are never undertaken by the lobster. This fact makes possible the rapid depletion of fishing-grounds, and even the practical extermination of the lobster in given areas; it also affords basis for the belief in the efficacy of artificial means for maintaining and increasing the supply.

There are well-marked movements of the lobster induced by various influences, among which are the abundance or scarcity of food, the water temperature, and the spawning instinct. On the United States coast there is in the spring months a shoreward movement of large bodies of lobsters; on the approach of winter the lobsters move out into deep water.

FOOD.

The principal food of the lobster is fish, either dead or alive. Such bottom species as the sculpin, flounder, and sea-robin can doubtless be readily caught by the lobster, and they also consume a large number of invertebrates, among them being crabs and other crustaceans, clams, conchs, and other mollusks, starfish, sea-urchins, etc. Lobster eggs

have been found in a lobster's stomach, and algæ sometimes serve as food. Fish is the bait most extensively employed in the lobster fishery.

REPRODUCTION.

The reproductive function of the lobster is not generally understood, and until a comparatively recent date a number of important questions in relation thereto were undecided. From the standpoints of the commercial fishermen, fish-culturist, and legislator, it is necessary that the principal phases of this subject be clearly appreciated, in order that the supply may be maintained.

The principal spawning season for lobsters on the United States coast is summer, especially July and August, when probably three-fourths of the lobsters deposit their eggs. The remaining egg-producing lobsters lay during the fall and winter. A given lobster does not spawn oftener than every second year, as has been shown by recent studies conducted by the Commission.

The eggs are fertilized outside the body of the female. The spermatic fluid is deposited in a receptacle at the base of the third pair of walking legs, and retains its vitality for a long time. When the eggs are being extruded, the female lobster lies on her back and folds the tail so as to form a kind of chamber to retain the eggs. After their discharge from the body, the eggs become coated with a cement substance secreted by glands in the swimmerets; this substance hardens after being in contact with the water and firmly unites the eggs to the hair-like filaments on the swimmerets. The exact method by which the fertilizing principle is conveyed to the eggs from the pouch in which it is contained is not known.

The incubative period is much prolonged. After the eggs are extruded and become attached externally, they are carried 10 or 11 months before hatching ensues; during this time they are carefully protected, and are perfectly aerated by the active motion of the swimmerets. On the United States coast most of the lobsters emerge from the egg in June, although some of the hatching is completed in May and some in July or even later. A few eggs are now known to hatch in winter. All of the embryos do not come from the eggs at the same time, the hatching occupying a week or more. The young receive no attention from the adults, but lead an independent existence immediately after escaping from the egg.

The lobster egg is about $\frac{1}{16}$ inch in diameter. When newly laid it is usually of a dark-green color, but is sometimes light-grayish or yellowish-green.

The known maximum number of eggs produced at one time by a lobster is 97,440; the average from lobsters taken for market is 10,000 to 12,000. The number depends largely on the size of the lobster, apparently in conformity to the following rule: The numbers of eggs laid by given lobsters vary in a geometric scale, while the lengths of the lobsters vary in an arithmetic scale.

The following table illustrates, with approximate accuracy, the egg-producing capacities of lobsters of the lengths indicated under normal conditions:

Length of lobster.	Number of eggs laid.
8 inches	5,000
10 inches	10,000
12 inches	20,000
14 inches	40,000
16 inches	80,000

MOLTING AND GROWTH.

The act of shedding the shell, or molting, is important and critical. It is only after shedding that growth takes place; during the early stages of the lobster's existence this function is often exercised in a comparatively short time, while later it occurs only at long intervals. Molting in the lobster consists in throwing off the entire external skeleton, together with the lining of the digestive tract.

The first molt takes place about the time the young emerges from the egg, when it is about a third of an inch long, and many lobsters do not survive this. During this first stage the larval lobster swims at or near the surface. A second molt ensues in from 1 to 5 days, and the lobster enters on its second stage, its average length being about two-fifths of an inch and its habits similar to the first stage. In 2 to 5 days another molt takes place, and the length of the larva increases to about half an inch. This is followed in 2 to 8 days by another molt, and the lobster enters on the fourth stage, when its length becomes slightly greater. From 10 to 20 days later the fifth molt ushers in the fifth stage, after which the surface-swimming habit is discarded and the larva goes to the bottom and begins to assume the characteristics of the adult. This stage lasts 11 to 18 days, and in it the young lobster has attained a length of about three-fifths of an inch. From this time on the molts are at longer and longer intervals until the fully mature condition is reached, when shedding takes place only once in one or two years.

The food of lobsters during the larval stages consists chiefly of small crustaceans. A very pugnacious instinct then characterizes them, and active cannibalism prevents their artificial rearing for lack of abundant natural food.

Larval lobsters are very susceptible to the influence of the sun (heliotropic) while in the first three stages, being attracted by bright rays to the surface of the ocean or to the side of a vessel. This peculiarity is lost during the fourth stage.

During the first year the young lobster, which since the fourth stage has become more and more like the adult in form and habits with each molt, attains a length of about 2 or 3 inches. At the end of the second

year the length is 5 to 7 inches. By the end of 4½ or 5 years a length of about 10 inches is reached. The rate of growth, however, depends greatly on the environment, the abundance of food being a very important factor.

The adult lobster usually molts in summer, and in the case of the female, shortly after the hatching of the eggs. As several months are required for the new shell to acquire the hardness of the old; as newly-laid eggs are rarely found on a soft-shell lobster; as molting does not ensue while the eggs are on the swimmerets; and, furthermore, as dissection has shown that the ovaries of a lobster whose eggs have recently hatched are in an immature condition and will not yield eggs until the succeeding year, it follows that the mature lobster deposits eggs not oftener than once in two years, with an alternating molt.

SIZE AND WEIGHT.

The average size of lobsters caught for market is now much less than it was in the earlier days of the fishery, and their average weight is probably not over 2 pounds. A lobster 9 inches long weighs, on an average, 1⅙ pounds; a 10½-inch lobster, 1¾ pounds; a 12-inch lobster, 3 pounds; and a 15-inch lobster, 4 to 5 pounds; while a lobster 20 inches long weighs 20 pounds or more. Lobsters weighing as much as 15 or 20 pounds are uncommon, and those weighing over 20 pounds are very rare. Up to a recent date, the largest lobster of authenticated weight was about 25 pounds. In 1897, however, 3 lobsters, each weighing over 30 pounds, were taken off Sandy Hook, N. J., the weight of the largest being 33 pounds.

The male lobster weighs more than the female of the same length, the difference in 11-inch lobsters, for instance, being about a quarter of a pound.

The size at which the lobster attains sexual maturity is a very important question. In the New England and Middle States and the Canadian Provinces the laws relating to the minimum size of marketable lobsters are quite various and illustrate the absence of definite information on this subject. In Maine, Massachusetts, New Hampshire, and New York the minimum limit of size of lobsters that may be sold is now 10½ inches; in Rhode Island it is 10 inches, and in Connecticut it is 9 inches. In the British Provinces the limit is much lower than in Maine.

Investigations conducted by the Fish Commission on the New England coast show that the female lobster attains maturity when from 8 to 12 inches long. Comparatively few lobsters under 9 inches in length lay eggs. Of over 1,000 egg-bearing lobsters collected at Woods Hole during a period of years, less than 2 per cent were under 9 inches long. On the other hand, by the time they have reached the length of 10½ inches most lobsters will have produced eggs, and this should be the minimum size permitted in the markets.

COMMERCIAL VALUE.

The lobster is the most important crustacean of the United States. It is the object of a special fishery, carried on with pots or traps, in all the coastal States from Delaware northward. and also in Nova Scotia, New Brunswick, Prince Edward Island, Quebec, and Newfoundland. In Maine, where the fishery is more important than in any other State, the lobster is the principal fishery product. Over 4,500 persons are engaged in this fishery in the United States; the capital invested is about $875,000, and the catch in 1896 amounted to 15,121,000 pounds, valued at $1,319,000. In 1880 the yield was larger (20,240,000 pounds), but the market value was much less, being only $488,000.

Between 1889 and 1899 the New England lobster catch decreased over 15,000,000 pounds, or 50 per cent, while the value increased more than $400,000, or 50 per cent. For a number of years this fishery presented the anomaly of a diminishing supply and an augmented catch, owing to the more active prosecution of the business; but the decline in the yield has for some time been unchecked, notwithstanding the employment of more apparatus and the prolongation of the fishing season. With a singular disregard for their own welfare, many fishermen have continually violated the State laws for the protection of small, immature lobsters and females bearing eggs. Only the rigid enforcement of restrictive measures by the States and the extensive artificial propagation of the lobster can ward off the destruction which threatens this valuable fishery.

INCEPTION AND PROGRESS OF LOBSTER-CULTURE.

If egg-bearing lobsters were not liable to destruction by man, artificial propagation would hardly be necessary. Notwithstanding the enactment of stringent laws prohibiting the sale of "berried" lobsters, the frequent sacrifice of such lobsters, with their eggs, and of many immature lobsters, has seriously reduced the lobster output and rendered active and stringent measures imperative. By the present methods millions of lobster eggs are annually taken and hatched that would be lost, and the females producing them, amounting to several thousands, are liberated.

Prior to 1885 experiments had been conducted at various points looking to the artificial propagation of the lobster. The only practical attempts of this nature previous to those made by the Fish Commission were by means of "parking," that is, holding in large naturally inclosed basins lobsters that had been injured, soft-shelled ones, and those below marketable size. Occasionally female lobsters with spawn were placed in the same inclosures. One of these parks was established in Massachusetts in 1872, but was afterward abandoned; another was established on the coast of Maine about 1875. It was soon demonstrated, however, that the results from inclosures of this character, so far as the rearing of the lobsters from the young were concerned, would not be sufficient materially affect the general supply.

LABORATORY, HATCHERY, AQUARIUM, AND MUSEUM, U. S. FISH COMMISSION, WOODS HOLE, MASS.

RESIDENCE, U. S. FISH COMMISSION, WOODS HOLE, MASS.

The completion of the new marine laboratory and hatchery at Woods Hole in 1885, with its complete system of salt-water circulation, permitted the commencement of experiments in artificial hatching on a large scale, which had not been practicable theretofore, although small quantities of lobster eggs, as well as those of other crustaceans, had been successfully hatched. In 1886 the experiments had progressed so successfully that several million eggs were collected and hatched at Woods Hole, the fry being deposited in Vineyard Sound and adjacent waters. From 1887 to 1890, inclusive, the number of eggs collected was 17,821,000.

From the eggs collected up to 1889 the average production of fry was about 54 per cent. During these years experiments were conducted as to the best method of hatching the eggs. The various forms of apparatus used were the Chester jar, the McDonald tidal box, and the McDonald automatic hatching-jar. In 1889 the results secured in the latter form of apparatus were so much better than with the others that it was adopted, and in 1890, from the 4,353,000 eggs collected, over 81 per cent yielded fry. Work was continued at Woods Hole on about the same scale until 1894, when the collections aggregated 97,000,000 eggs. In the same year lobster propagation was undertaken at Gloucester and a collection of 10,000,000 eggs was made there.

During the fiscal year 189 ; the number of eggs taken by the Fish Commission was 105,188,000, the resulting fry liberated numbering 97,579,000, or about 93 per cent; and in 1897 the collections amounted to 133,562,000 eggs, of which 115,606,000, or 90 per cent, were hatched.

COLLECTION OF EGG-BEARING LOBSTERS.

Although the new eggs appear on the lobsters during the months of July and August, no special effort is made to secure egg-bearing lobsters until the following spring. The collections usually commence in April and continue until the middle of July. At Woods Hole it has been the recent practice to receive at the station and place in the hatching-jars during the fall and winter any lobsters having external eggs that may be captured by local fishermen. The collecting-grounds extend from New London, Connecticut, to the eastern end of Maine. For Woods Hole station eggs are secured from fishermen operating between New London, Connecticut, and Plymouth, Massachusetts.

The most important grounds in Connecticut are in the vicinity of New London and Noank; in Massachusetts, New Bedford, South Dartmouth, Plymouth, Woods Hole, and numerous localities in Buzzards Bay and Vineyard Sound. Eggs for the Gloucester station are secured from the fishermen operating between Boston and Rockland, which territory comprises the most important lobster fishery in the United States. The schooner *Grampus* is used in making the collections between Portland and Rockland, the lobsters being delivered at Gloucester early in the season and later on to the steamer *Fish Hawk*, which is stationed at a suitable point in Casco Bay.

As the laws of Massachusetts, New Hampshire, and Maine prohibit the holding of the "berried" lobsters by the fishermen, arrangements are made with the State authorities by which certain officials of the Fish Commission are appointed deputy wardens and authorized to hold egg-bearing lobsters for fish-cultural purposes in live-boxes. Early in the spring all of the lobster fishermen in the territory referred to above are visited by agents of the Commission, who arrange with them to hold all of their egg lobsters in live-cars until called for, at a price agreed on.

Collections are made from Woods Hole and Gloucester by steam launches and sailing vessels. The steam launches visit the near points three to four times a week to obtain egg-bearing lobsters. The vessels collect at more distant points in Connecticut and Maine. Local agents at Boston and Plymouth, Massachusetts, and Kittery Point, Maine, also collect egg-bearing lobsters, which are held in live-boxes until the agent has a sufficient number to make a trip. On the arrival of the vessel or launch at the station the lobsters are transferred to tanks supplied with running water and held until the spawn-taker is ready to strip the eggs.

TAKING AND MEASURING THE EGGS.

The receptacle into which the spawn-taker strips the eggs from a lobster is either a glass jar (9 inches in diameter) or a water-bucket, which, after thorough cleaning, is partly filled with water.

The operator, with his left hand, grasps the lobster from above and turns it on its back, lowering it into the spawning-vessel head downward. By pressing it firmly against the sides of the jar it is prevented from using the anterior part of its body or its mandibles. The hand is then slipped farther back toward the tail and the segmented portion of the body is held firmly to prevent its closing. The lobster is then ready for stripping. A rather dull, short-bladed knife is used to separate the eggs from the swimmerets, to which they are attached by hair-like fibers; stripping begins at the last pair of swimmerets and gradually proceeds toward the body. As the eggs are scraped off they fall into the water in the jar. Some which adhere to the claws of the lobster are washed off by means of a small stream of water. The lobster is then put back into a tank, where it remains until liberated.

Lobsters received by the local agents at Boston and Kittery Point are held until a suitable quantity is on hand and are then stripped, the eggs being taken to the station in transportation cans and the adults released. Early in the spring the eggs stand transportation well, but late in the season, as incubation becomes more advanced, they are very delicate and are quickly affected by rough handling or sudden changes in temperature.

Before being transferred to the hatching-vessels the eggs are accurately measured, generally with a glass graduate, into which they are poured, the water being drawn off. The basis of measure is an ounce, which contains about 6,090 eggs.

HATCHING APPARATUS AND OPERATIONS.

Experiments conducted during a series of years having demonstrated that the automatic hatching-jar was the best form of apparatus for hatching lobster eggs, it has been adopted at the stations of the Commission since 1889. A full description of this jar is given in the article on shad-culture, pp. 150–152. The manipulation and operation of the jar is practically the same as with shad eggs, except that frequently, where the water supply is inadequate, three jars are connected by means of rubber tubing and the water used over and over. This is accomplished by connecting the overflow from the first jar with the supply to the second and so on, but can only be done during the early stages before the fry commence to hatch. When first placed in the jar the eggs are matted together by the fine hair-like fibers, but after a few days they separate and work very much like shad eggs.

From 400,000 to 500,000 eggs (equivalent to about 2 to 2½ quarts) are usually placed in each jar, although at times when the hatchery is crowded a few more may be successfully cared for.

The fry pass voluntarily from these jars to cylindrical glass jars, 9 inches in diameter and either 9 or 18 inches high, placed in the center of the table and covered with cheese-cloth at the top to prevent their escape.

The period of incubation depends entirely upon the age of the egg when collected. For example, eggs taken in October do not hatch until the following May, whereas eggs collected in June frequently hatch in 24 hours after being placed in the jars. During one season eggs collected from December 12 to January 25, numbering 1,717,000, at a temperature of 45°, commenced hatching May 25 at a temperature of 54°. To determine how soon the new-laid eggs can be taken from the parent and hatched artificially, collections were begun early in July and continued until fall, for several seasons, the eggs being placed in hatching-jars at the Woods Hole Station; all those collected prior to October 15 died. In November, 1895, 15,000,000 were placed in jars and carried through the winter under very unfavorable conditions, but hatched with a loss of only 50 per cent. The density of the water at Woods Hole varies from 1.023 to 1.025, its average temperature being from 49° to 64° during the months of April, May, and June.

THE LOBSTER FRY.

Owing to the cannibalistic habits of young lobsters when closely crowded, it has been the policy of the Commission to liberate the fry as soon after hatching as possible. They are taken out in ordinary 10-gallon transportation cans, about 200,000 being placed in a can for short shipments and 125,000 for long shipments, and liberated in the vicinity of the grounds from which the adult lobsters were taken. When this is impracticable, they are liberated in Vineyard Sound and Buzzards Bay with an outgoing tide, so as to insure their wide distri-

bution. The question of the transportation of lobster fry any great distance is still an unsettled one, as in but few instances has it been attempted to ship them by rail, and then the trips were comparatively short—namely, from Woods Hole to Cold Spring Harbor, New York; from Woods Hole to Provincetown and Plymouth, and from Gloucester to Kittery Point. The shipments from Woods Hole have all been very successful, and there seems little doubt that the young lobster will stand transportation for 24 hours with excellent results.

DEPARTMENT OF COMMERCE AND LABOR
BUREAU OF FISHERIES
GEORGE M. BOWERS, Commissioner

THE GERMAN CARP IN THE UNITED STATES

BY

LEON J. COLE

APPENDIX TO THE REPORT OF THE COMMISSIONER OF FISHERIES TO THE SECRETARY OF COMMERCE AND LABOR FOR THE YEAR ENDING JUNE 30, 1904

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THE GERMAN CARP IN THE UNITED STATES

By LEON J. COLE

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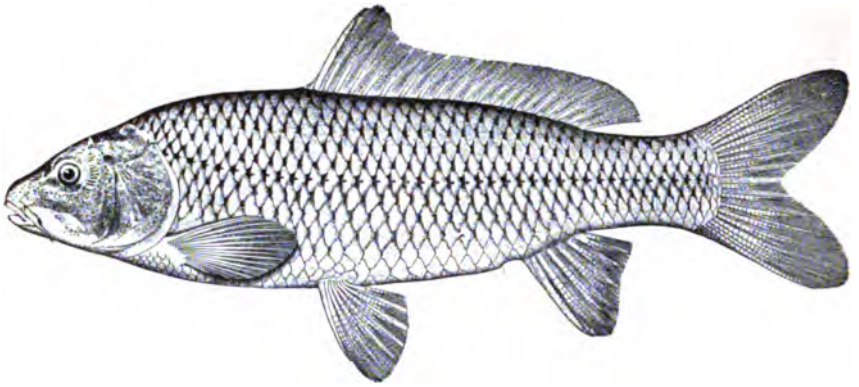

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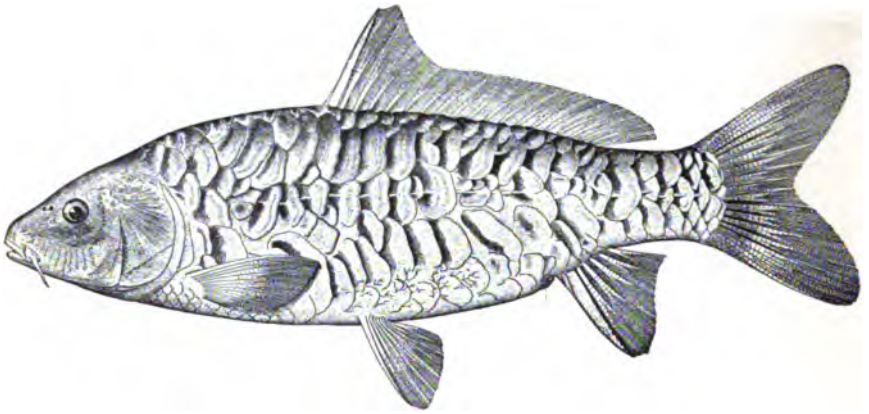

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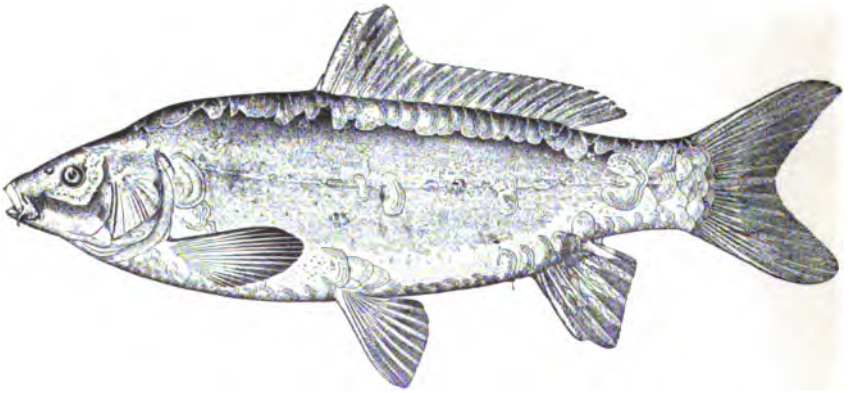

3. Leather carp.

THE GERMAN CARP.

THE GERMAN CARP IN THE UNITED STATES.

By Leon J. Cole.

INTRODUCTION.

For a number of years there appears to have been in many sections of this country an increasing popular prejudice against the German carp. These fish were distributed very generally throughout the United States something over twenty years ago, with the idea that they would be extensively raised in ponds and so provide a supplementary income from small inland waters which were unsuitable for other fishes, or from land upon which artificial ponds could be constructed. It was inevitable that many of the fish should escape into the natural waters of the country; and within a few years many of our rivers and lakes were teeming with carp, for which, at that time, there was little or no market. With persons who had been able to obtain in abundance many species of our finer native fishes, the coarser flesh of the carp found little favor, and, under the circumstances, it was perhaps but natural that prejudice should arise, especially because the carp was supposed to be injuring the existing fisheries. In some cases the adverse opinions were founded upon facts and a knowledge of the habits of the fish; more often they were the repeated hearsay born of suppositions and complete ignorance of the subject or of misinterpreted observations. The newspapers also took the matter up, and the carp was decried on all sides without stint.

In the summer of 1901, in order to obtain evidence upon the matter, the writer was appointed by the United States Bureau of Fisheries (then the United States Commission of Fish and Fisheries) to make an investigation of the habits of the carp and to gather any available information relative to its usefulness or obnoxiousness. The work was done in connection with the general biological investigation of the Great Lakes under the general direction of Prof. Jacob Reighard, of the University of Michigan. Professor Reighard was not in active charge of the work, however, in 1901, Prof. H. S. Jennings, then also at the University of Michigan, acting as director during that season. I take pleasure in thanking both Professor Reighard and Professor Jennings for their interest in the investigation and for their readiness at all times to do everything in their power to further the work.

Probably the two regions in the United States where carp are found most abundantly are about the western end of Lake Erie and in the Illinois River and its tributaries. This investigation was begun, however, at Lake St. Clair, this locality being chosen because of such complaints as the following, which appeared in a Port Huron paper:

FISH IN LAKE ST. CLAIR—THE CARP ARE RAPIDLY DESTROYING ALL THE OTHER KINDS.

G——— B———, an old fisherman, who has plied his trade on Lake St. Clair three miles above Mount Clemens for twenty-three years, says in three years more there will be no fish except carp left in the lake. The carp eats the spawn and destroys the perch, bass and other good fish in those waters, and the supply is already much reduced. Mr. B——— suggests that the government offer a bounty of 3 cents or so for the destruction of the carp in order to save the other fish.

This particular paragraph is quoted because it gave the starting point for the field work, and because it illustrates so well the general tone of complaint against the carp. The shallow bays of the delta occupying the upper fourth of Lake St. Clair afford an excellent place for carp—except that possibly the water averages a little cold for their most prolific development—and they are to be found there in considerable numbers. Furthermore, the usual comparative clearness of the water makes it easier at times to observe the fish than in the muddier waters in which they are usually found. When the carp are rooting about in the bottom for food, however, even clear water is made so roily that there is little chance to watch them.

After about three weeks at the St. Clair Flats, the remainder of the summer, until August 31, was spent on Lake Erie, especially at the upper end. During the last week in August all of the important wholesale fish houses on the west and south sides of Lake Erie, from Detroit to Buffalo, were visited to obtain figures as to the magnitude and value of the carp fisheries of the lake. In November, 1901, about three weeks were spent on Lake Erie, principally at Port Clinton and Put-in Bay, in order to determine the relation of carp to the whitefish, which were in the height of their spawning season at this time.

In 1902 it was not practicable to begin the field work until after the 1st of July. As before, Lake St. Clair was first visited, but the conditions there being unfavorable on account of heavy storms, which made the water roily, investigations were renewed on Lake Erie, especially at Port Clinton and at Sandusky. During the last season of the investigations, in the summer of 1903, with headquarters in Sandusky, the work was conducted for about three weeks, during the spawning season of the carp, most of the time from a camp in the marsh, some 20 miles above the city, near where the Sandusky River opens into the large bay of the same name.

In addition to the observation of the general habits of the carp in waters where it has become adapted to a new environment in such a short time, several special problems were kept in mind. Thus a study

was made of the abundance and distribution of carp in relation to the conditions existing at various places, and measurements and records were taken to determine if possible whether the fish had changed perceptibly in accommodating itself to these conditions.

Most of the time, however, was given to the more strictly economic side of the question, and hence, either on account of their uncompleted state or because of their technical nature, the results of certain lines of the study have been omitted from the present report. One of the more strictly economic questions was the relation of the fish to aquatic vegetation, the destruction of which was being deplored, particularly by sportsmen, who maintained that the best food of many of the ducks, such as the canvasback and redhead, was fast being destroyed by the carp. It was also to be determined how far, if at all, carp interfere with the spawning of other fishes, and whether they eat the eggs and prey upon the young of other fishes, and if so, to what extent. It was claimed that they were especially detrimental to bass and white-fish—the former one of the greatest favorites of the sportsman, the latter one of the most valuable food-fishes of the Great Lakes.

Offsetting the possible harm done by the carp to vegetation and to the fisheries must be its own value as a food-fish; for the carp fishery has within the last few years, in the regions of the carp's greatest abundance, grown to be an industry of no mean proportions. Must the carp, then, be unconditionally condemned, or should we find that, if properly utilized, its value would compensate for the degree of damage it undoubtedly does? It is hoped that the conclusions reached in the following pages may do much toward settling this question, though there are still many points upon which fuller information is desirable.

In order to make the report more useful to those who are interested in the carp, it has been thought best to include a general description of the fish, its habits, and its history. The figures of the different varieties of carp here reproduced (pl. I) are from drawings made for the Bureau of Fisheries from fish in its ponds in Washington soon after the introduction of the species into this country. The photographs and other figures are by the author.

It is impracticable to mention here all to whom I am indebted for assistance of one kind or another in the prosecution of my investigations. I am under especial obligations, however, to Messrs. Cleaver, of the firm of R. Bell & Co., Port Clinton, who not only furnished me a place in which to work in their fish house, but placed at my disposal, without cost, whatever carp were necessary for my work. The Bense Fish Company (which has since changed hands), of the same city, extended to me similar privileges. It was frequently necessary for me to call upon Mr. S. W. Downing, superintendent of the Bureau of Fisheries hatchery at Put-in Bay, for aid, which was furnished with

uniform courtesy. Through the kindness of Prof. Herbert Osborn I was enabled, when in Sandusky, to make my headquarters at the Lake Laboratory of Ohio State University, where I had the use of a table for considerable periods during the summers of 1901 and 1902. And, finally, I wish to express my gratitude to the many fishermen who took great interest in my work, who gave me whatever information was at their disposal, who permitted me to accompany them on their fishing trips, who shared with me their food, and who were my companions in camp for weeks at a time. Other special acknowledgments have been made in their proper places throughout the report.

THE SPECIES *CYPRINUS CARPIO* LINNÆUS.

DESCRIPTION.

Within the past decade the carp has become so generally distributed throughout the United States and so abundant in some places that nearly everybody is more or less familiar with it in a general way, but it has been almost universally neglected in the descriptive works in this country, further than a simple statement of its occurrence. It may therefore be well to give a brief description of the carp and its principal varieties.

The carp belongs to a family of fishes (Cyprinidæ) best represented in America by the minnows (especially of the genus *Notropis*) which abound in most of our lakes and streams. In the eastern United States the members of this family are all small, the largest rarely attaining 18 inches in length, while the smallest is scarcely 2 inches long when adult. The Old World species are generally much larger than this, and on the Pacific coast there are a few which reach a length of 5 or 6 feet, and which are also apparently more closely related to the European forms in structure.

Scientifically the carp is known as *Cyprinus carpio*, the name given to it by Linnæus. It varies greatly in many of its characters, a condition probably brought about in large part by its state of domestication, or semidomestication, for a number of centuries. In shape it varies from a long, rather slender fish (pl. I), whose height scarcely equals one-fourth its length, to a deep form nearly or quite half as high as long. The greatest height is at the anterior end of the dorsal fin. In all cases, however, the body is rather strongly compressed laterally, the cross section never approaching close to circular. The greatest breadth is normally a short distance back of the head, but the bodies of female fish are often, before the breeding season, distended with roe to a considerably greater breadth. This dimension in normal individuals usually equals less than half the height. The snout is blunt, and in typical forms the dorsal outline rises from the snout in a nearly uniform bow or arch to the base of the dorsal fin.

The length of the head, from the tip of the snout to the posterior edge of the gill-cover or operculum, is in the neighborhood of one-fourth the length of the fish[a], but is usually considerably less than the height. It varies considerably in individuals and with age. The eye is situated slightly less than halfway back on the head and on a line from the tip of the snout to the upper end of the branchial opening. The eyes are not quite circular, but are elongated slightly in a direction parallel to the dorsal side of the head, and their long diameter is contained six to seven times in the length of the head. The mouth when closed is nearly horizontal, the gape reaching about halfway to the anterior margin of the eye. At the corners of the mouth are two short barbels, usually a little longer than the diameter of the eye, yellow or reddish in color, which are, however, longer than two olive colored ones on the upper jaw. Both sets are variable, and, according to Seeley (1886, p. 95), may be unsymmetrical on the two sides or frequently wanting entirely.[b] The lips are rather thick and fleshy, adapted to vegetable feeding, the lower somewhat shorter than the upper. The tongue is smooth. The palate is covered with a white and very sensitive skin ("carp's tongue"). The nostrils lie immediately anterior to the eyes and are double, those of each side being separated by a small projecting flap of skin. The anterior nostril is the larger.

The dorsal fin arises anterior to the median point in the length of the fish and slightly in advance of the ventrals, and extends back even with the posterior end of the anal fin. The base of the dorsal fin equals rather more than a third of the length of the body, and its greatest height (at the second and third soft rays) is equal to about a third of its length. After the first two or three soft rays, of which there are 18 to 22 in all, the remainder are only one-half to two-thirds as high, so that the free margin of the fin has a rather sharp reentrant angle at this point. Three or four (usually three) spiny rays precede the soft rays, the most posterior one being the stoutest and longest, with the extreme end usually soft and flexible; this soft portion is often broken away in older fish, however, leaving the ray with a hard, sharp point. The posterior border of this ray is serrated, the serrations or teeth, which have their points directed downward, lying on each side of a median groove and increasing in size from below upward.

The height of the anal fin is greater than its length at the base, which is about equal to one-fourth the length of the base of the dorsal. It is composed of 3 spiny rays and 5 or 6 soft, articulated rays. The second stout, spiny ray is similar to that of the dorsal fin. The first of the

[a] Throughout the description "length" is considered from the tip of the snout to the *base* of the caudal fin, or, more strictly speaking, to the posterior edge of the hypural bones, which is found in practical measuring by cutting the flesh away a little and probing with a steel point. For general purposes this measurement can be taken to the last scale in the lateral line.

[b] I, myself, have noted no cases in which they were absent.

soft rays is the longest, and the succeeding ones decrease gradually in size to the last, which is about one-half the length of the first.

The ventral or pelvic fins are made up of 2 spiny rays each, a long and a short one, and 8 or 9 soft rays. The height is much greater than the length at the base, but when folded back the fins do not reach as far as the beginning of the anal fin. The pectoral fins have each 1 stiff ray and 15 or 16 jointed ones, are rather elongated with rounded extremity, and reach back almost to the base of the ventrals.

The caudal fin is large, broad, and equally lobed, with the ends of the lobes rounded. The posterior notch is rounded, not very acute, and extends in half the length of the fin or less. It is made up of 18 or 19, or occasionally only 17, jointed rays, not counting the short incomplete rays (usually 4 to 6) outside the first long one on each side. The longest rays of the caudal fin are usually shorter than the head, and never exceed it in length.

The body of the typical scale carp is uniformly covered with large thick scales which approach a polygonal, four or five sided outline. In the lateral line, which extends nearly straight from the upper angle of the opercle to the middle of the base of the tail, or may be bowed slightly downward, there are 35 to 39 scales. Above the lateral line are 5 or 6 rows, and below a similar number. The scales are largest on the anterior part of the sides, where their diameter equals about one and one-half times that of the eye. Usually less than one-fourth of the scale is exposed; this portion is thicker and has a radial, fanlike ornamentation. The portion of the scale which is concealed by those in front of it is marked by fine concentric lines, which in turn form bands of varying width and regularity, and which are correlated with the growth of the scale. The middle of each scale of the lateral line is traversed by a small oblique or slightly curved tube, in which the sense organs of the lateral line are situated, and the cephalic canals of the lateral line system are noticeable on the suborbital ring.

In coloration the carp is fully as variable as in its other characters. In general the sides are yellowish, golden, or greenish, shading into a darker color on the back, which may be dark olive, or bluish-green, or almost black with a greenish cast. The yellow of the sides often becomes richer, approaching to orange on the ventral side between the anal and caudal fins. The yellow of the sides shades into whitish on the belly. The posterior edge of each scale has a dark border, and there is usually a dark blotch on the anterior part of the exposed portion, the two together forming a reticulated, or netlike pattern over the fish, with a dark spot at the anterior angle of each mesh of the net (fig. 1, pl. I). The lips are yellow or orange; the rest of the head is dark olive, except the cheeks, which are yellowish, while the under side of the head is light yellow or whitish. The iris is yellow.

The dorsal fin is olive or dark gray, each interray space being

darker in its posterior half; the rays themselves are of about the same color. The anal is yellowish-red, while the pectoral and pelvic fins are grayish or yellowish, tending to red toward their tips. The upper lobe of the caudal fin is of about the same color as the dorsal; the lower lobe has a lighter, yellowish cast, with more or less red, especially toward the end.

The coloration is influenced by the age of the fish, the character of the water in which it lives, its nutrition, the season of the year, its sexual condition, and by the other conditions of its environment. Seeley (1886, p. 97) states that unsymmetrical coloring is sometimes found and that a fish may have glittering golden stripes on one side of the body and pale steel blue on the other. Sometimes typical carp are black, bluish, green, red, golden, silvery, or even white, and Doctor Fatio records that he has kept in confinement carp which were originally green or golden, but which became colorless in an opaque vase. It is not an unusual thing to see in carp that have died out of water a reddish suffusion, especially marked in the fins, probably due to the congestion of blood in the capillaries as the circulation is stopped.

In common with the other members of the family, the mouth of the carp is without teeth, the only organs of this description being the blunt, knob-like structures lying on the pharyngeal bones in the back part of the mouth, or "throat." These are entirely for grinding food, and, as is obvious both from their position and shape, are of no use in grasping, this function being performed by the so called lips. The alimentary tract is comparatively long, but uncomplicated; the stomach is a simple tube not sharply differentiated from the esophagus and without a blind sac, while the intestine has no pyloric appendages. The entire alimentary tract from the beginning of the stomach[a] is usually two to two and one-half times as long as the body. The air bladder is large, with tough, thick walls. A transverse constriction divides it into two parts; the posterior of these is the smaller and ends in a rounded point, while the anterior portion is larger and has its base somewhat bilobed.

RACES AND VARIETIES.

The great range and frequency of variation in the carp is undoubtedly largely due to its domestication or semidomestication since early times. As is to be expected, this has resulted in the naming of a large number of varieties or races. In Europe, where carp culture is carried on systematically, these races are kept pure and true, so far as possible; but in this country no attention has been paid to them, at least in recent years, so that we need not treat them in detail here. Those interested in the subject will find an exhaustive account in the contribution entitled "Über Karpfenrassen," by Dr. Emil Walter, in

[a] The position of the thoracic septum is here taken as the beginning of the stomach.

the recent book by Knauthe (1901). These names have often been given specific value and were bestowed usually either for characters of the integument or of form (cf. Günther, 1868, p. 26); thus we have such names as *Cyprinus macrolepidotus*, *C. rex cyprinorum*, *C. specularis* (for the mirror carp), *C. nudus* (leather carp), and *C. cirrosus*, *C. regina*, *C. hungaricus*, *C. elatus*, *C. acuminatus*, etc., and *C. hybiscoides*, a variety with the fins much prolonged. This list of synonyms might be extended much further.

Hessel (1881) considers all the varieties of carp as falling into three chief groups, which he distinguishes as follows (op. cit., p. 867):[a]

1. *Cyprinus carpio communis*, the scale carp; with regular, concentrically-arranged scales, being, in fact, the original species improved.
2. *Cyprinus carpio specularis*, the mirror carp; thus named on account of the extraordinarily large scales, which run along the sides of the body in three or four rows, the rest of the body being bare.
3. *Cyprinus carpio coriaceus*, or *nudus*, the leather carp; which has on the back either only a few scales or none at all, and possesses a thick, soft skin, which feels velvety to the touch.

Walter (Knauthe, 1901), however, says the scale, mirror, and leather carp must not be considered as distinct species or races, although the conditions of the scales are characteristic, since a similar differentiation of the scales, or at least a tendency to it, is found in every true race of carp. In many ponds where one of these forms (i. e., scale, mirror, or leather) has been raised, the others have appeared spontaneously. He concludes that they should be considered only as varieties. He goes on to say that the ordinary characters are so inconstant and variable that sharp lines can not be drawn between the various intergrading races. In his opinion, the division into races should depend principally upon the relations in size of various parts or measurements of the body, though he correlates with this set of characters three others, viz, (1) rate of growth (i. e., the ability for rapid growth); (2) adaptability to climatic changes, and (3) time of sexual maturity. He then develops a rather artificial classification, depending mostly, as he says, upon the two ways in which the flesh is disposed upon the back; that is, whether there is a large development of the dorsal musculature, forming a highly arched outline, often with a hump and a reentrant angle back of the head, or whether the dorsal outline is low and comparatively straight. He uses as a measure of this the ratio of the height of the body to the length. This ratio is designated by the letter V in the following classification, translated from his paper (p. 85):

I. Cultivated races; V=1:2 to 1:3.
   (*a*) High-backed cultivated races; V=1:2 to 1:2.6.
   (*b*) Broad-backed cultivated races; V=1:2.61 to 1:3.
II. Primitive and degenerate races; V=1:3.01 to 1:3.6.
   Here belong also those forms under the size ratio 1:2 to 1:3 which do not have a breadth in correspondence with their size ratio.

[a] The blue carp, so called, is probably but a color phase, and not a true "variety."

It seems probable, however, that the character of the scales should be placed with the other four categories of characters given above as being another modification brought about by artificial breeding and selection and not as a condition due simply to conditions of domestication, as is sometimes supposed. All of these characters are probably heritable, although some of them, such as rate of growth and time of sexual maturity, may undoubtedly be readily influenced by external conditions in the individuals of a single generation. Furthermore, there apparently can be all combinations of these characters, and the so-called different varieties and races are the fish possessing the various combinations. In general, it may be said that the most highly specialized carp are those which are destitute of scales, which grow quickly, are high in proportion to their length, and tend to have a hump back of the head, and which become sexually mature at an early age.

These various forms of carp probably differ in no essential way, except that they are not so well differentiated and established, from what are spoken of as "breeds" by stock breeders. There would appear to be no valid reason for calling those with the different character of scales "varieties," and to class those which are differentiated as to form as "races." It is merely that the most obvious characters are those which have become most permanently established by selection, namely, character of scales first and form second. Walter claims that ability for quick growth has also been fixed in certain stocks. Thus a fish of good quick-growing stock may later make a good growth even if poorly nourished during its first or second year, whereas a fish of poor stock under similar conditions would be permanently stunted. The hardiness, or ability to resist climatic conditions, he says has not yet been made permanent in any stock, though it is claimed that scale carp possess the ability to a greater degree than the others. The adaptability to climatic conditions probably becomes reduced rather than increased as the other characters are developed.

All intermediate stages are found in the sets of characters mentioned. For example, fish may be entirely covered with scales, but the scales are larger and fewer in number than on the regular scale carp, and, similarly, one finds all gradations between the leather and the mirror carp. The same thing is true of the form of the body. This is especially the case with the fish in our waters, where all kinds have become established and have interbred until there is a complete series in the gradation of characters in almost any lot of fish taken, and a division of them into varieties must be an arbitrary one. As a matter of convenience in my work, those fish which had larger and fewer scales than typical scale carp I called mirror carp. Some authors state that the leather carp should be entirely destitute of scales; others that it may have a row of scales along the back and a row on each side. In no case in the Great Lakes did I see a carp entirely

destitute of scales, and those which are nearly bare are few compared with those entirely scaled. Of nearly 3,000 fish counted at random at various times and at different places about Lake Erie, something over 91 per cent might be called scale carp, and I should judge that at Lake St. Clair the percentage was even higher. It is very probable that under the present free conditions of life of these fish, with the constant interbreeding, they are gradually returning to the primitive scaled condition, and although there are no data to show the rate at which this process may have been progressing since they have become established in our waters, a few years more may see an even smaller proportion of mirror carp than there is at present.

HYBRIDIZATION.

Not only does the interbreeding of the different varieties of carp (using the word "variety" in its broad sense) cause confusion, but all these varieties cross readily with certain closely related species of fishes, giving rise to a number of hybrid forms. The commonest of these is a cross between the ordinary carp and the so-called crucian carp (*Carassius vulgaris*), a common fish in Europe. The resulting hybrid was described as a distinct species before its true nature was known, and was given the name *Carpio kollarii*. It is often known in Germany as the "poor man's carp." In general it is intermediate in character between its two immediate ancestors, but often resembles *Cyprinus carpio* so closely that it can be distinguished only with difficulty. Hessel (1881, p. 868) made the following experiments in crossing in order to settle the question of what resulted from the various crosses. He says:

> In order to determine this question, I myself managed to bring about such crosses by placing (1) female common carp with male crucian carp, and (2) female crucian carp with male common carp, in small tanks, constructed with this end in view; (3) I also put together female *Carpio kollarii* with male common carp; this for the sole purpose of testing the capability of propagation of the *C. kollarii*, which had been doubted. In the two former cases I obtained forms analogous to the *Carpio kollarii* sometimes approaching in appearance the true carp, at others the crucian carp. In the third case, however, having placed ripe *Carpio kollarii* together with *Cyprinus carpio*, I obtained a product with difficulty to be distinguished from the genuine carp. I took the trouble to feed them for three years, in order to try their fitness for the table, but their flesh was exceedingly poor and very bony and could not be compared by any means to that of the common carp.

Hessel remarks upon the frequency of this cross throughout Europe, and says that in many instances it is cultivated by pond owners, who suppose that they have the true carp. So far as I am aware the crucian carp has not been introduced into this country. But the carp is also said to cross readily with the gold-fish (*Carassius auratus*), tench (*Tinca tinca*), and some others. The first of these is already abundant in some of our waters, though the others have not as yet, at any rate,

become well established.[a] This is a matter of considerable importance, for whatever may be our opinion of the carp as a food fish, we certainly do not want it any poorer than it is. For this reason it would seem that efforts should be made to prevent the introduction of the crucian carp in our waters, and to restrict, so far as possible, the spread of gold-fish, tench, and other fishes with which the carp may hybridize with a resulting deterioration of the food value of the race.

SIZE, GROWTH, AND AGE.[b]

There appears to be but little definite information as to how long carp may live, and what size they may attain. It is said that they may live to be 100 or even 150 years old, and may come to weigh 80 to 90 pounds, but these statements are generally based upon insufficient evidence. That the fish do commonly reach a weight of 30 to 40 pounds, however, seems quite certain, and Hessel (1881, p. 874) says: "It is a well-known fact that two large carps, weighing from 42 to 55 pounds, were taken several years ago on one of the grand duke of Oldenburg's domains in Northern Germany," and also claims to have had in his possession some scales 2½ inches in diameter, which came from a Danube carp that weighed 67 pounds.

The largest carp I have myself seen from the Great Lakes would not weigh much over 20 pounds. That the fish do attain a much larger size is, however, certain. Mr. W. Cleaver, upon whose information I can rely, tells me that in the spring of 1903 he received from Sandusky Bay a female carp which weighed 30 pounds after spawning. According to the ratio between the weight of the ova and the entire weight of the fish found in another case, before spawning this fish would have weighed, in all probability, fully 37 pounds. From the fishermen, both at Lake St. Clair and at Lake Erie, I often heard of carp weighing 30 and 40 pounds, but these were only estimates and not based on actual figures. That there are at present to be found in these waters carp weighing more than 40 pounds I doubt.

As has already been stated, the rate of growth of carp (as is true of most fishes) depends in a great measure upon the temperature of the water in which the fish lives and the abundance of suitable food. Under ordinary conditions in open waters of temperate regions they will reach a weight of 3 to 3¼ pounds in three years (Hessel, 1881, p. 873),

[a] Goode (1888, p. 418) says the tench has become well acclimatized in the Potomac. Dr. H. M. Smith, however, informs the writer that the tench is not numerous in the Potomac, but the gold-fish is abundant and has become one of the regular market fishes at Washington. It has lost the brilliant coloration it had when it escaped from the Government ponds, and now has the dull brown color of the primitive type; the fish is not recognized in the market, and is sold under the name of "sand perch."

[b] It is maintained that the age of carp may be told with considerable accuracy by means of the successive lines of growth upon the scales, similarly to the way that the age of a tree is determined by counting the annular rings. Persons interested in this subject will find a full discussion of it by Dr. Emil Walter in the book on carp-culture by Knauthe (1901), chapter III, pp. 88-122, "Die Altersbestimmung des Karpfens nach der Schuppe."

but in warmer climates the growth is very much more rapid, and sexual maturity also is attained at an earlier age. Numerous examples of the rapid growth of carp in the warmer waters of this country have been reported. Thus in a report of the Illinois Fish Commission (Illinois, 1884, p. 10) will be found the following statement by Doctor Adams, of Spring Hill Park, Peoria, with regard to some fish received by him from the State:

At less than 2 years of age one of the carp weighed 9¼ pounds, measuring 22 inches in length, a growth of over 1 pound a month from the time it was placed in warm water.

Doctor Adams had previously had the fish in a spring where the water was cold, and they had not done well. Many more statements may be found in the early reports of the United States Fish Commission.

Goode (1888, p. 414) takes from Cholmondeley-Pennell's "Fishing" the following very good table giving the comparative weights and lengths of carp:

Length.	Weight.	Length.	Weight.	Length.	Weight.
Inches.	*Lbs. Oz.*	*Inches.*	*Lbs. Oz.*	*Inches.*	*Lbs. Oz.*
9	7¾	17	3 4¼	25	10 6¾
10	11	18	3 14¼	26	11 11
11	14¾	19	4 9	27	13 2
12	1 2¼	20	5 5¼	28	14 10
13	1 8¼	21	6 2¾	29	15 4
14	1 14¼	22	7 1¼	30	16 0
15	2 4	23	8 1¾		
16	2 11¼	24	9 3¼		

THE COMMON NAME.

For the sake of completeness a word as to the name of the carp may not be out of place. According to Day (1880–1884, p. 159):

Carp has been derived from the Greek term "kuprinos," itself said to be from "kupris" or "Cyprus," where Aphrodite or Venus was first worshiped, and may have been given to this fish in order to symbolize its extraordinary fecundity. Holme (1688) gives *seizling* as yearlings, next a *sprole* or *sprale* from 2 years of age, terms taken from Gesner's Swiss names of this fish, they not being called "karpf" until 4 years old. In the last century we are told (Whole Art of Fishing, 1719) it was called the *fresh-water fox* and *queen of rivers*. *Cerpyn*, Welch. *De Karper*, Dutch. *La carpe*, French.

In the United States it has come to be generally known as the German carp, because of its importance in Germany and its introduction here from that country. Some protest has been made against the use of the name, as the carp is not in the strict sense a German or even a European fish, but, like the term English sparrow, it is a name that is likely to persist. Both of these names are historically appropriate, so far as we are concerned, since they serve to indicate the source of the first[a] lots of each species introduced. In ordinary usage, however, simply the word "carp" is used, and it is so that the fish is known ·cially.

[a] caving out of consideration the rather doubtful introduction of carp into the Hudson France by Captain Robinson about 1830 (see p. 540).

THE CARP IN EUROPE.

The little that is known of the early history of the carp is given, with slight variation, in nearly all works which treat of the fish, and as I have nothing to add I shall here give merely a brief summary. There seems to be a general agreement that carp were indigenous to the temperate portions of Asia; and they had probably spread into southeastern Europe before the Christian era. Aristotle speaks of it as "a river fish without a tongue, but having a fleshy roof to its mouth; as producing eggs five or six times a year, especially under the influence of the stars; as having eggs about the size of millet seed; and as being occasionally struck by the dog-star when swimming near the surface" (Houghton, 1879, p. 15). It is also mentioned by a number of other writers of early times and is spoken of as an excellent article of food.

The carp probably came into western Europe by easy stages. Hessel states that its culture in Austria can be traced back as far as the year 1227, and it is claimed to have been introduced into Germany and France two or three decades later (1258). The extensive ponds at Wittingau, in Bohemia, were begun as early as 1367. Carp culture was carried on especially in connection with monasteries and on a number of large estates, and has come to be an important commercial industry, especially in Austria-Hungary and Prussia. It is said that an acre of water suitable for carp culture will rent for as much as an acre of land. The fish's range has gradually extended in Europe, until now it is found over practically the whole of the continent from Italy to Sweden and Norway, and from France and the British Isles to Russia and the boundaries of eastern Siberia. It does not do so well, however, and is little cultivated, in the more northern portions of its range, such as Scotland, Sweden, Norway, Finland, etc.

Peyrer (1876, p. 615) states that in Austria the "Danube carp" was once a favorite and cheap food of the common people, but that its numbers have become greatly decreased. A writer (Anonymous, 1880) whose paper has been translated in the Report of the United States Fish Commission for 1878, and Veckenstedt (1880) have given good descriptions of the carp fisheries of the Peitz Lakes in Nether Lusatia, some 60 to 80 miles to the southeast of Berlin. There are some 76 of these lakes, which are a royal domain and are rented to a private individual at an annual return equivalent to $12,870. The ponds are drawn in October, and this is the occasion for a general holiday in the region. The drawing off of the water is begun three weeks beforehand, and when the fish have congregated in the deeper places they are taken by means of large drag-nets, or seines, capable of holding 5,000 pounds of fish. At Cottbus, a near-by city, meets the so-called "Carp Exchange," composed of buyers from the large firms in Halle, Leipzig, Dresden, Magdeburg, Posen, Berlin, etc. The

raisers also convene to determine the price that shall be asked for carp. It is stated that from 200,000 to 300,000 fish are sold at Cottbus in a season, representing an aggregate weight of 800,000 to 1,000,000 pounds. After being weighed the fish are transferred to perforated boats—what we would call live-cars—and are transported down the canals and rivers to the large cities, where they are to be consumed. This is a slow and laborious journey, the cars often having to be carried over shallow places on rollers, and a week is required to get the fish to Berlin, while to reach Hamburg and Madgeburg takes four or five weeks. This is in striking contrast to our method of packing the fish in ice and shipping them 500 miles or more to market in a couple of days. The German method has the advantage of getting them there alive.

Just when and whence the carp came into England is not known. It is generally conceded to have reached there, however, between 1051, when it was not mentioned in the Anglo-Saxon Dictionary of Ælfric, and 1486, the date of first publication of the "Boke of St. Albans," where it is spoken of as "a deyntous fysshe: but there ben but fewe in Englonde" (see p. 529). Linnæus puts the date of introduction into England as 1600, and it is sometimes attributed to Mascall[a] in 1514; but probably he is responsible only for the extension of the range into Sussex (Day, 1880–1884, p. 163). In the privy purse expenses of King Henry VIII, in 1532, various entries are made of rewards to persons for bringing "carpes to the king" (Yarrell, 1836, vol. i, p. 306, from Pickering's edition of Walton, p. 207, note). All recent writers agree that the oft-quoted "doggerel lines of—

> 'Turkies, carp, hop, pickerel, and beer
> Came into England all in one year'

may be considered interesting as verses, but not faithful representations of facts."

Day (1880–1884, p. 163) gives the date of the introduction of carp into Sweden as 1560[b] and into Denmark as 1660; but de Broca (1876, p. 279, footnote) says they were taken to Denmark more than a hundred years earlier, in 1550, by Pierre Oxe. Malmgren (1883), in an address to the bureau of agriculture of the imperial senate of Finland, advises against any attempt to raise carp in that country, as he thinks that on account of the climatic conditions it would not pay. They were introduced into Finland in 1861, when Chamberlain Baron v. Linder placed some in the ponds of his estate of Svartå, but they are said to have died out after a few years. Some attempts were made prior to 1861, but they were all failures. Malmgren says that Holstein and Courland are the most northerly countries where carp culture

[a] Sometimes written "Marshall."

[b] In his "Fishes of Malabar," Day (1865, p. xii) remarks: "Block observes that in his time, 1782, g to the degeneration of the species in the north, due to the coldness of the climate, several s were yearly dispatched from Prussia to Stockholm with further supplies of live carp."

is successfully carried on, and that even in Schleswig the people complain of lack of success. Nevertheless, "in 1879 a landed proprietor in Schoren [the most southerly Province of Sweden] commenced to raise carp in ponds; and there is a reasonable prospect that this kind of fish culture, if carried on rationally and cautiously, will prove profitable, because carp can easily stand the climate in the southern part of Sweden" (op. cit., p. 377). However, all attempts of King John III to raise carp on the island of Oeland proved futile.

In Norway carp were, when Malmgren wrote, acclimatized in only two places—near Farsund, in the southernmost part of the country, and at Milde, near Bergen. In Russia they were said to be found in some of the imperial ponds near St. Petersburg and near the convent of Walamo, but there was no attempt at carp culture.

These records of the northerly extension of the carp in Europe are of interest when we compare them with its distribution in North America.

INTRODUCTION AND DISTRIBUTION OF CARP IN THE UNITED STATES.

It is uncertain when the first carp were introduced into the United States. This may have been done at any time by private individuals, though if such was the case the fish were probably only kept in tanks or small ponds as curiosities, for it is certain that with the exception of their establishment in California they never gained a general distribution or attracted much attention until their successful introduction by the Fish Commission in 1877. Certain early writers mention the presence of carp in American waters, but there can be little or no doubt that they have misapplied the name to some native fish. Thus, in the Report of the Commissioners of Fisheries of Massachusetts (Massachusetts, 1866), quoting the early colonists of New England, occur the following lines in reference to the Connecticut River:

> In it swim salmon, sturgeon, carp, and eels,
> Above fly cranes, geese, ducks, herons, and teals.

And again, in his history of the Fisheries of Chesapeake Bay and its Tributaries, McDonald (1887) takes from the diary of Col. William Cabell, of "Union Hill," Nelson County, Va., the statement:

> 1769, Oct. 25: Caught 2 fine carp in our traps.

These traps were set in the James River, and in this case at least we can easily see what fish may have been mistaken for the carp, since the so-called carp-sucker (*Carpiodes cyprinus*), which in a superficial way greatly resembles the true carp, occurs abundantly in the waters of that region. A much more recent case is given by Clark (1887, p. 735), who takes from Ricketson's History of New Bedford[a] (Massachusetts) the statement following.

[a] 1858, p. 403.

In 1858 the varieties [of fishes] to be found in the waters of New Bedford were: Fresh-water: Trout, perch (white, red, yellow), pickerel, chub, carp, silverfish, minnow, hornpout, eel, clam.

But as other evidence of the occurrence of the carp in Massachusetts at that time is lacking, we must again conclude that the identification was at fault.

In 1842, however, the name of the carp appears in scientific literature, being included by De Kay (pp. 188–190) in his list of the fishes of New York. He remarks upon its introduction as follows (p. 189):

I am not aware that any attempt has been made to introduce the carp into this country previous to the year 1831, which, it will be seen by the following letter from Henry Robinson, esq., of Newburgh, Orange County [New York], was attended with complete success.

"I brought the carp from France in the years 1831 and 1832, some 2 or 3 dozen at a time, and generally lost one-third on the passage. I probably put into my ponds 6 or 7 dozen. They soon increased to a surprising degree, and I have now more than sufficient for family use. I have not paid much attention to their habits, but I have noticed that they spawn twice a year; first about the middle of May, and again in July. It is said in France that they spawn three times, but I have not observed it. During the period of spawning, which lasts about ten days, it is very amusing to watch their operations. They come up to the surface, and the females deposit their spawn along the sides of the pond among the grass, where they are impregnated by the males as they are emitted. During this process, they keep the sides of the pond in a foam with their gambols, and it is not difficult at that time to take them with your hands. They grow quickly, reaching 3 or 4 inches the first year, but after that time their growth is very slow. The largest I have taken yet have not exceeded 10 or 11 inches, my ponds being too small for them to equal the size of those you see in Europe. They are very shy of the hook; I generally bait with small pieces of fresh bread, (of which they are very fond,) made up into small pills with the fingers, and at the same time drop a small piece of bread into the water near the hook, when they bite readily. My ponds are supplied by springs of pure and clear water, but they keep the water in such a state that they cannot be seen at the bottom.

"For the last four years past, I have put from 1 to 2 dozen carp every spring in the Hudson river near my residence. They have increased so much that our fishermen frequently take them in their nets. They are larger than those in my ponds."

There are several other references in the literature to apparently the same introduction. In the Transactions of the American Institute (1851) for 1850, page 397, in a discussion before the Farmers' Club, we find the following:

Mr. Meigs.—We are pleased to see among us Captain Robinson, of Newburgh, who brought the Carp from England several years ago—thus conferring a great benefit upon his country by adding a fish before that unknown in our waters.

Captain Robinson.—I brought the Carp from France about seven[a] years ago, put them into our Hudson river, and obtained protection for them from our Legislature, which passed a law imposing a fine of $50 for destroying one of them. I put in Gold Fish at the same time. Now some of these Carps will weigh 2 pounds, and some of the Gold Fish, which are a species of Carp, are quite large, some of them being pure silvery white. Both kinds are multiplying rapidly.[b]

[a] There is here a discrepancy in the date. If, as Robinson says in his letter to De Kay (above), he brought the carp to this country in 1831–32, seventeen years would come nearer to it than seven.

[b] This discussion is noted by E. E. Shears (1882).

From both the preceding quotations it appears that Captain Robinson had been planting young carp in the Hudson regularly since their establishment in his pond. According to a writer in Forest and Stream, who signs himself "R." (1874), these were further augmented a few years before that date by the bursting of the dams of Captain Robinson's ponds. He says:

More than fifty years ago[a] Captain Henry Robinson, owner of one of the Havre packets, brought the first carp and goldfish to this country from France. He placed them in a small pond on his place in the southern part of this village [Newburgh, N. Y.]. Several years ago, when the dam of the pond broke away, many of the fish escaped into the river. They appear to multiply very rapidly, and any number might be obtained from the fishermen about the bay.

Finally, in the Bulletin of the United States Fish Commission for 1882, we find the following letter (dated New York, May 31, 1882), to Professor Baird from Mr. Barnet Phillips (1883):

To-day Mr. James Benkard, vice-president of our fish cultural association, told me that his grandfather, Capt. Henry Robinson, had, about 1830, first brought carp from Holland [sic] and put them in his ponds at Newburg, and that he had therefore reason to suppose that the carp in the Hudson were derived from these. In Frank Forester's "Fish and Fishing," of 1849, page 166, you may find a statement to this effect, which Mr. Benkard says is substantially correct.

I have thought these data might be useful when the whole history of the carp in American waters is to be written up.

In spite of the positive statements in the foregoing quotations there still seems to be some question as to whether the true carp was found in the Hudson prior to the time of its introduction into the country by the Fish Commission. In the letter to Professor Baird from Mr. Shears (1882), dated January 26, 1881, and already quoted, he says:

I notice that the gold-fish are quite plenty in the river in this vicinity [Coxsackie, Greene County, N. Y.]; also a fish about the size and shape, which is called a silver-fish, but they do not correspond to Captain R[obinson]'s description of the silver-fish. These are nearly or quite as dark as a rock-bass. I have seen none that would weigh over one pound and a half. When caught in fykes by the fishermen, they are usually pronounced unfit to eat and thrown back in the river. However, last fall I saw them peddled through the streets, and the fishermen told me they could catch scarcely any other kind, and they sold as well as perch or bass. I have not had an opportunity to taste any of them, therefore am no judge of their flavor.

It is to be noted that he makes no mention of the carp. That Professor Baird was inclined to the opinion that there were no true carp in the Hudson is shown by the following paragraph taken from his report for 1877 (U. S. Fish Commission Report, 1879, p. *43):

Considerable discussion has arisen as to the person to whom the introduction of the carp into America is due; indeed, it is claimed that this was done many years ago. Certain fish-ponds on the Hudson River are said to have been emptied of their contents by a sudden freshet, and, as a consequence, the Hudson is now full of what

[a] Here, again, there is a discrepancy in the date. The introduction of the fish could not have been more than forty-three years before.

is called the carp and sold as such in the New York market. I have not yet, however, been able to find a single fish among those sold as carp which is really any other than the common gold-fish, reverted to its original normal condition. Indeed, in the olivaceous fish caught in great numbers in the Hudson there are usually found precisely similar specimens of white, red, and all intermediate conditions. While, therefore, I can not say that no genuine carp were transferred to the Hudson, none have come under my observation; and it has occurred to me as possible that the Prussian carp, *Cyprinus carassius*, L., may have been the one introduced, or possibly the hybrid progeny of this and the true carp may have been gradually mixed with the gold-fish.

If we could know whether the description given by De Kay (1842, p. 188) was made by him from specimens taken in New York, or whether he merely copied what he gives from some European writer, we might be able to throw some light on this subject. Certain it is that his description disagrees in a number of points with that of the true *Cyprinus carpio*, but it is apparent that some of these are inaccuracies, as they do not agree either with the Prussian (or crucian) carp or with the hybrid, the so-called *Cyprinus kollarii*. The most important points in this connection are, perhaps, that he gives the length as 6 to 12 inches, and describes the "nape and back" as "rising suddenly." True carp in the second or third year, under ordinary conditions, should attain a length of more than 6 to 12 inches, while the hybrid rarely exceeds 8 inches in length (Seeley, 1886, p. 104). It is noteworthy, too, that Captain Robinson in his letter to De Kay (p. 540) states that his fish grew quickly, reaching 3 or 4 inches the first year, but after that time their growth was very slow, while the largest he had taken from his pond did not exceed 10 or 11 inches. He adds, however, that those subsequently taken from the river were larger than those in his ponds.

Even more significant, it seems to me, however, is the statement that the nape and back rise suddenly, for though this may be in some of the more highly cultivated races of carp, it is not usually the case, especially when they have bred out of the confinement of ponds for a time, where no artificial selection is made. On the other hand, the description forcibly suggests the broad shape of the hybrid mentioned, which in outline approaches the crucian or Prussian carp, *Carassius vulgaris*. That this last is not the fish meant by De Kay is shown by his statement that the fish has four barbels.

As matters stand, we shall probably never know whether the fish brought over by Captain Robinson were true carp or whether he happened when procuring the fish in France to get hold of specimens of the hybrid form, which occurs in abundance in many parts of Europe. It makes little difference which they were, however, since the comparatively little stock in the fresh waters of southeastern New York could have little influence on the multitude of fish, from a new importation, which was spread broadcast over the country a few years later.

The circumstances attending the successful introduction of the scale carp into California, in 1872, by Mr. J. A. Poppe, of Sonoma, are better known. Mr. Poppe left California for Germany in the spring of 1872. At a place called Reinfeld, in Holstein, he procured 83 carp of various ages and sizes (cf. Poppe, R. A., 1880, p. 663), the three largest of which were 2 feet or more in length, the smallest "the length of an ordinary steel pen." The fish were placed in 22-gallon tanks arranged one above the other, so that the water flowed down from the highest to the lowest, when it was dipped back to the top. These were put aboard a steamer for New York. Many of the carp died on the way, the larger ones going first, and only 8 reached New York alive. These were taken across the continent to San Francisco in safety, but 3 more were lost before reaching Sonoma, where Mr. Poppe arrived on the 5th of August, 1872, with only 5 of the smallest of the 83 fish with which he started. Ponds had already been prepared, and the surviving carp were placed in them at once. They did well from the first, and, according to Mr. Poppe in the report mentioned above, they spawned the next spring, by which time they had reached a length of 16 inches! It was estimated that in May (1873) there were in the ponds over 3,000 young carp. The young fish were sold to farmers throughout California and adjacent states, and some were shipped even to Honolulu and Central America. The report gives a list of persons in Sonoma County who undertook the culture of the fish, and states that at that time (presumably 1878) Los Angeles, San Bernardino, and the adjacent counties in the southern part of the state were well supplied with the fish, and reports were coming in from all quarters that they were doing remarkably well.

There seems to be some question, also, as to whether the fish introduced by Mr. Poppe were a pure strain, for Professor Baird (U. S. Fish Commission Report, 1879, p. *44), who examined some specimens that were sent to him, says:

> These are scale carp, apparently somewhat hybridized; at least, they do not present the characteristics of the pure breed brought by Mr. Hessel:[a]

He here refers to the fish introduced under the direction of the Fish Commission, the subject which we will now consider.

The question of the introduction of the carp into the United States was taken up by the Fish Commission within a few years after the organization of that Bureau. The first mention of it occurs in the report for the years 1872 and 1873 (U. S. Fish Commission Report, 1874, pp. lxxvi, lxxvii) under "Fishes especially worthy of cultivation." Professor Baird, at that time Commissioner, there says:

> Sufficient attention has not been paid in the United States to the introduction of the European carp as a food-fish, and yet it is quite safe to say that there is no other

[a] Goode (1888, p. 417) says: "Those [carp] introduced into California a few years ago by Mr. Popp were an inferior strain of Scale Carp."

species that promises so great a return in limited waters. It has the pre-eminent advantage over such fish as the black bass, trout, grayling, &c., that it is a vegetable feeder, and, although not disdaining animal matters, can thrive very well upon aquatic vegetation alone. On this account it can be kept in tanks, small ponds, &c., and a very much larger weight obtained, without expense, than in the case of the other kinds indicated.

It is on this account that its culture has been continued for centuries. It is also a mistake to compare the flesh with that of the ordinary *Cyprinidæ* of the United States, such as suckers, chubs, and the like, the flesh of the genuine carp (*Cyprinus carpio*) being firm, flaky, and in some varieties almost equal to the European trout.

It was not the intention of the Fish Commission to introduce the carp into waters that were already stocked with good native species, nor was it claimed that the carp was superior to the majority of our indigenous food fish. But it was believed that it could be successfully raised in many sections of our country not favorable to the growth of better fish. In this connection Professor Baird remarks in a subsequent report (U. S. Fish Commission Report, 1879, p. *41):

There are several species of American *Catostomidæ* which might in all probability answer in some measure, if not fully, in place of the carp. Among them are especially the buffalo fish, a large sucker, the flesh of which is much esteemed. As, however, some special varieties of carp have been developed and had their instinct of domestication established, while experiments on our indigenous species are scarcely yet tried, there is no reason why time should be lost with the less proved species.

In another place (U. S. Fish Commission Report 1873–4 and 1874–5, p. xxxvi) he enumerates the good qualities of the carp which made it a desirable species for cultural purposes in the United States. These are given as follows:

1. Fecundity and adaptability to the processes of artificial propagation.
2. Living largely on a vegetable diet.
3. Hardiness in all stages of growth.
4. Adaptability to conditions unfavorable to any equally palatable American fish and to very varied climates.
5. Rapid growth.
6. Harmlessness in its relation to other fishes.
7. Ability to populate waters to their greatest extent.
8. Good table qualities.

Nearly all, if not all, of our American food fishes are carnivorous, preying for the most part upon smaller fish of all kinds. The increase of these forms is therefore necessarily limited, especially in small bodies of water, where it is difficult to keep them supplied with food. The large-mouthed black bass (*Micropterus salmoides*), which has been extensively used for stocking rivers and lakes throughout the country, is a good example. But where strictly a food fish was required, it seemed that one at least in large part a vegetable feeder possessed far greater advantages, and, as stated above, no native fish answered these requirements so well as the carp.

In the winter of 1876–77, Mr. Rudolph Hessel, in the interests of Fish Commission, as an initial experiment shipped carp from

Bremen to Baltimore, but, owing to a storm of unusual severity to which the vessel was exposed, all were lost on the way. He immediately returned to Europe, however, where, at Höchst, near Frankfurt, he procured another lot of fish. These he succeeded in bringing in safety to New York, and on May 26, 1877, they were placed in ponds in Druid Hill Park, Baltimore. This lot consisted of 345 fish, of which 227 were naked and mirror carp, and 118 were common scale carp. The ponds at Druid Hill Park not being sufficient for the proper care of the fish, Congress allowed use to be made of the Babcock Lakes in the Monument lot, in the city of Washington, and appropriated the sum of $5,000 to put these in proper condition. In the following spring these ponds were ready for the reception of the fish, and 65 leather carp and 48 scale carp were transferred to them from the Druid Hill Park ponds.

The fish that remained in Baltimore, under the care of Mr. T. B. Ferguson, spawned in 1878, but some gold-fish had entered the pond accidentally, and the carp hybridized with these, so that instead of having young true carp there were some 2,000 hybrid young. These were destroyed as being worthless. The results were more satisfactory in 1879, in which year about 6,000 young were reared. Of these, 2,750 were distributed to applicants throughout Maryland, the remainder in other states. In this year the fish in the ponds at Washington spawned for the first time, and about 6,000 were also reared there. Altogether, in 1879, some 12,265 carp were distributed to over 300 persons in 25 states and territories. Among the recipients were various state commissioners, who redistributed their fish to applicants in their respective states.

Applications for carp had begun to come in as early as the fall of 1876, and the number increased rapidly in the succeeding years. In 1877 there were 22 applications, in 1878 144, and in 1879 235, while in 1880 there were nearly 2,000.

In 1879 new ponds were constructed at Druid Hill Park, and it was in this year, also, that a new importation of carp was made from Germany. These were brought over by Dr. O. Finsch (1882), a German naturalist, who obtained 100 mirror carp from Mr. Eckhardt, of Lübbinchen. These were small fish, a year and a half old and only 6 to 8 inches long. Only 23 reached New York alive, although the water was aerated by pumping air into it, and ice was used to keep the temperature down. The fish were shipped from Hamburg in coal-oil barrels, and Dr. Finsch attributes the large mortality to the fact that one of the barrels was not clean, and to the warm weather. The survivors arrived in New York on the 6th of May, whence they were shipped to Washington without loss and turned over to Mr. Hessel, the superintendent of the Washington ponds.

In the succeeding years the demand for carp steadily increased, and the fish were furnished in great numbers by the Fish Commission, being sent to all parts of the United States, and some shipments being made to other countries. We find in the reports of the Commission that in several successive years carp were sent to Canada, and in 1882[a] they were also distributed to persons in Ecuador, Costa Rica, and the City of Mexico. In 1882 over 7,000 applications for carp were filed, and 5,758 applicants were supplied with 15 to 20 carp each, 143,696 fish being distributed in this way. With an appropriation of $12,000 made by the Forty-sixth Congress, the breeding ponds were extended until there were some 20 acres of ponds devoted to raising this fish.

In this year, also, an attempt was made to bring carp eggs to this country. On May 31, Mr. George Eckhardt arrived from Germany with two cases of carp eggs, packed after a method that had been found successful for transportation for shorter distances; but when the eggs were examined here they were found to be dead and covered with fungus. The effort had been made only as an experiment, and was so far unsuccessful, on account of the long time required for the journey, that it was not repeated. Another importation of the adult fish, however, is recorded in 1882, when, as a return for favors extended to the Deutsche Fischerei-Verein, Herr von Behr forwarded to the Commission a number of the so-called blue carp, "a variety believed to be of particular interest, and which has not been hitherto cultivated by the Commission." When these arrived on January 4, 1882, it was found that 19 of them were of "pure blood," while 4 were hybrids. The hybrids were destroyed and the others turned into the Government ponds.

As illustrating how thoroughly carp were disseminated throughout the United States in these early years of its introduction, the data for 1883 furnish an interesting example. In that year carp were sent into 298 of the 301 Congressional districts, representing 1,478 counties; in this way 260,000 carp were distributed, in lots of 20, to 9,872 applicants. The distributions continued large until about 1890, when they began to diminish, and were finally discontinued in 1897. The following table gives the approximate figures for the distribution from 1880 to 1896:

[a] Records taken from United States Fish Commission reports have reference to fiscal years beginning July 1. Distributions of carp were made in the fall of the calendar year preceding the date designating the fiscal year—i. e., distributions in the fiscal year 1882 were made in the fall of the calendar year 1881.

Carp distributed by the United States Fish Commission.

Fiscal year.	Number of fish.	Fiscal year.	Number of fish.
1880	12,265	1889	170,402
1881	66,165	1890	26,316
1882	143,696	1891	338,809
1883	259,188	1892	157,093
1884	162,000	1893	72,481
1885	167,948	1894 [a]	47,757
1886	348,784	1895	33,935
1887	133,769	1896 [b]	87,208
1888	175,410		

[a] In 1894 400,000 young carp were used for feeding bass.

[b] In 1896 about 600,000 young carp were used for feeding bass, and since that date all the carp hatched by the Government have been used for the same purpose.

At the present time the carp has come to have a very general distribution, especially in the temperate portions of the world. Its distribution in Asia and Europe has already been mentioned (p. 537). It is now found in abundance all over the United States wherever the waters are at all suitable. Many were sent to Canada by this Government shortly after the introduction of the species, but with the exception of some of the waters of Ontario, especially in the vicinity of the Great Lakes, it does not appear to have become very abundant, owing without doubt to the coldness of the waters. From this country a number of lots were sent to Ecuador, Costa Rica, and Mexico, where it was said to be thriving. It was introduced into the Hawaiian Islands from California, and Cobb (1902, p. 452) reports it as being found now on the islands of Maui and Kauai. On the former it is quite common in the irrigation ditches near Wailuku, where it is said to have been first planted. The fish are not often sold, as they are not popular with the whites and natives on account of their muddy flavor, but they are caught and eaten by the Japanese and Chinese.

In reference more particularly to the history of the carp in the Great Lakes region, there can be little doubt that prior to 1879 there were no carp here. In that year the first distribution was made by the United States Fish Commission, and those who received fish were 6 applicants in Ohio, 5 in Indiana, 2 in Illinois, and 1 in Wisconsin. In the following year a large number of persons in these states received carp either directly from the United States Commission or indirectly through their state commissions, and the real introduction of this fish into the waters of the Great Lakes basin may be said to date practically from that year. This was only twenty-five years ago, and the wonderful increase of carp since that time is in many ways comparable to that of the English sparrow in this country.

The distribution of carp in 1880 did not take place until late in the year—in November for the most part—and it is not likely that many reached the public waters that fall. Many of them surely did so the following season, however, to say nothing of those that were planted

there directly by the government and state commissions. There was at this time a fever of enthusiasm for carp culture throughout all parts of the United States. From the time of the proposed introduction the Fish Commission had published many papers, including a number of translations of German articles, giving much information on the habits of the carp and its desirable qualities, and explicit directions as to the methods in vogue in raising carp in Germany, where this industry is most important. The newspapers took the matter up and were loud in its praises, but neglected to give so large a share of attention to the practical side of the question—to the care and attention the fish should have in order to make the venture a success. Most men are interested at once when they think there is a chance of getting something for nothing, and here seemed to be an opportunity to have a perpetual supply of fresh fish for anyone who had land with any kind of a mud hole on it that would hold a few bucketfuls of water. Accordingly applications for carp piled in, and were filled as soon as possible. As a result of ignorance and neglect, a large proportion of these fish or their offspring were soon undoubtedly in the public waters—largely from the breaking of dams of improperly constructed ponds, and two years later (in 1883) came reports of their being taken in considerable numbers by fishermen in the rivers and lakes.

Besides the stocking of the public waters which occurred accidentally, many fish were also purposely planted in them. In 1881 the Ohio State Fish Commission put 40 carp into the Maumee River (Ohio Fish Commission Report, 1882, p. 1435), and in May of the same year some were planted in Ten Mile Creek. These were 2½ inches long when liberated, and it is reported that in the following September and October a number were caught which would weigh 4½ to 5 pounds, while one had a weight of 8 pounds. In the same report we read that 12 carp were given to Mr. Charles Carpenter, of Kelleys Island, which is in the very midst of the breeding grounds of the white-fish, and 17 to Mr. Edward Lockwood, on the (Catawba) Peninsula. Both of these lots doubtless contributed sooner or later to stock the lake. Indeed, one of the first lots of carp sent out from Washington was in November, 1879, to Mr. Lewis Leppelman, Fremont, Ohio (Smiley, 1886, p. 792), which is on the Sandusky River, and probably there is no place in the United States to-day where carp are much more abundant than in the waters of Sandusky River and Bay. In July, 1883, however, Mr. Leppelman thought he still had all his fish, so they could not have contributed to the first stocking of the river and lake.

One of the earliest records I find of the taking of carp in Lake Erie, where they are now so abundant, is given in a compilation by Mr. C. W. Smiley (1886, p. 738) among the statements of those who received carp of the Fish Commission. This is the statement of J. C. Sterling, of Monroe, Mich., December 10, 1883, that one of the

Monroe fishermen found in his catch of white-fish the previous week a fine specimen of German carp which weighed 3¾ pounds. The pound from which the fish was taken was in Lake Erie, about three-fourths of a mile out from the mouth of Raisin River. I was unable to learn from the fishermen of this region the exact year when they began to catch carp, but all agreed that it was "in the early eighties." I was told that when the first carp were taken no one about the fish houses knew what they were, and they were kept on exhibition in tubs as curiosities. It is needless to say that they are no curiosity there now, when hundreds of tons are shipped from a single place in the course of a year.

About this same time carp began to be taken by the fishermen in the waters of the Mississippi River and its tributaries. Early in July, 1883, a fisherman at Naples, Ill., on the Illinois River, caught a mirror carp weighing 5 pounds. At Pekin a mirror carp was taken which weighed 6 pounds, and at Meredosia, also on the Illinois River, another, with a weight of 8 pounds (Illinois Fish Commission Report for 1883, pp. 10–12). Carp which had escaped from ponds were also taken at or near Hannibal, on the Mississippi, and young carp were taken at Quincy. Their numbers have increased to a remarkable extent, until now the carp forms the most important fishery product of Illinois.

The Great Lakes are, on the whole, not well suited to carp. Their sandy or rocky bottoms near shore are hard and wave beaten, and support at the best a very scanty vegetation, while they slope off so quickly to a considerable depth that the sun has little chance to raise the temperature of the shallow water to that degree of warmth most favorable for these fish. The western end of Lake Erie and Lake St. Clair, especially at its upper end, on the broad delta formed by the St. Clair River and known as the St. Clair Flats, are exceptions. In the latter place the shallow bays often possess soft, muddy bottoms, and are filled with animal and plant life similar to that found in the smaller inland lakes. These conditions suit the carp well, and it is found there in great abundance. Even better are the conditions in Lake Erie, for the whole upper end of the lake is of inconsiderable depth, while into it open rivers and bays with hundreds of square miles of flat, muddy, reed-grown marshes, which furnish ideal feeding and breeding grounds for a fish like the carp. It is probable that the fish breed, for the most part at least, in the marshes; but they are often fully as abundant in the lake itself. Just what relation they have to the two places—to the marshes and to the open lake—has not been definitely determined, but the probability of their migration from one to the other, with possibly more or less regularity, will be discussed later.

The most extensive marshes connecting with Lake Erie are those of Sandusky Bay and Sandusky River, which opens into it, the marshes

along the Portage River above Port Clinton, at Monroe, Mich., and at places along the north shore. These last I have never had opportunity to visit. Marshes of less extent occur at Erie, Pa., and at other places along the south shore.

It must not be supposed from what has been said that the carp are by any means limited to the places mentioned in Lake Erie and Lake St. Clair and in the waters of the Mississippi River and its tributaries. As a matter of fact they are usually present in numbers in any of the inland lakes and streams of the region which are suitable for them, and especially near the mouths of many of the rivers emptying into the Great Lakes, which usually have more or less extensive marshes for some distance back. This is true of nearly all the streams which open into the lower end of Lake Huron, Lake St. Clair, and Lake Erie, and into the St. Clair and Detroit rivers, connecting them. It is due to a slight tilting of the earth's crust to the southeast, which has caused the waters to flood the lower courses of the streams and produce what are known as "drowned channels." The marshes along the western side of Michigan are probably due for the most part to a simpler cause. There the sand, which is thrown up by the waves and has been blown up into immense dunes, tends to choke up the mouths of the streams entering Lake Michigan, causing them to flood the country many miles back. Such marshes are found along the Kalamazoo, Black, and Grand rivers, and at Muskegon and other places along the lake, in all of which carp are plentiful.

That the extensive carp fisheries are at present confined to so few localities results from a number of causes, among which is not so much the relative abundance of the fish as the ease with which it may be taken. The shallow shores of Lake Erie and the equally shallow bays of the St. Clair flats afford excellent places for hauling a seine—an operation which is often attended with great difficulty or is well nigh impossible in the marshes, where the bottom is soft and the water grown with weeds. Local laws also, in some places, interfere with the seining of carp.

HABITS AND SPECIAL SENSES OF THE CARP.

Observing wild carp under natural conditions requires much care and a great deal of patience. Under favorable circumstances, when not disturbed or alarmed, they may often be seen swimming lazily about among the weeds in shallow water, frequently with the dorsal fin projecting above the surface. Their mouths are constantly in motion as they breathe, taking in water and expelling it through the gills, and at the same time working about in the mud or over the surfaces of the water plants for food. The resemblance of their mouths to that of the sucker is at such times especially apparent. In spite of the appearance of taking life so easily, they have nevertheless the

ability for quick and powerful movement, for, let anything give the fish the least fright, there is a twirl, a splash, and it is gone. It is, in fact, a strong and rapid swimmer when it puts forth the effort. One who has occasion to search for carp comes to be able to recognize them almost without fail just by the way they make this sudden break and dash away, even if the water is so roily—as is often the case—that the fish can not be seen at all. If the water is more than a foot or so in depth, there is usually not a splash, although there is an audible sound, a sort of dull thud; the water boils up where the fish started with the first strong lash of its tail, and a disturbance of the water due to the rapid passage of the fleeing fish underneath shows the course as it dashes away. This it usually does in an almost straight line—that is, it does not zigzag about. If the water is clear, a glimpse of the fish may be caught; or, if among rushes or cat-tail flags, the movement of these indicates the line of retreat. If a considerable school of large carp is startled, and they go off in this way through the rushes, the whole surrounding growth will wave and rattle as if a sudden and erratic wind had struck it, the reeds twisting and bending in all directions at once. There are other fish, such as the fresh-water dog-fish (*Amia calva*) and some of the bass, which one will sometimes start up singly here and there among the rushes, and which will dart suddenly away; but anyone who ever chances to startle a school of carp in this way will have no trouble guessing the authors, if, indeed, it occurs to him to attribute so much commotion to fish at all.

This refers to carp in the open. In ponds they become easily tamed, learn to come to a certain spot to be fed, and, it is said, will even take food from the hand. This tameness in small ponds probably depends not only upon the familiarity the fish come to have with the surroundings and with people, but as well upon the fact that they are better fed and the struggle for existence is greatly reduced—their common enemies are absent, so that they get less exercise and tend to become more sluggish in temperament. To prevent this, it is the custom of European fish culturists to introduce into their ponds certain predaceous fish, such as pike, which keep the carp active and in good condition.

That carp are wary is well known to fishermen, who speak of them as "wise," "knowing," and "cunning." For this reason their capture is difficult. They usually avoid the ordinary form of set net, so that comparatively few are taken in fykes, traps, or pounds. Seines, once around them, are difficult to evade, and it is in this way that they are taken for the most part. But if a seine becomes torn or does not drag closely on the bottom they are quick to find the opening, while large numbers often escape by jumping out of water and clearing the cork line. Day speaks of this characteristic of the carp in his work on the

Fishes of Great Britain and Ireland (1880–1884, p. 160). To use his words:

> The fisherman finds this fish an adept at escaping from nets, by burrowing below it, or springing over the corks, . . . So difficult is it to net that . . . one can well understand the Norfolk pen-men regarding it with mysterious awe, how its entrances and its exits into pieces of water puzzle them, and how, as Lubbock remarks, they consider it as something more than a fish, and look upon it as what the Scotch term "no cannie."

Although I have spoken above of the carp's habit of ordinarily swimming about lazily and quietly, this is by no means always the case, for these fish often produce a considerable disturbance by their splashing. This is when they are feeding in shallow water, and will be discussed more fully when we come to consider the feeding habits. They also splash about considerably at the breeding time.

Carp exhibit a marked tendency to go about in schools. In regions where they are abundant, it is usual to find either a large number in a given locality, or else none at all. That these schools are frequently of great size is apparent from the fact that several tons of carp are often taken at a single seine-haul along the shore of the open lake, which is rather more conclusive evidence than is afforded when they are taken in a bay or other partially inclosed place.

Moderately warm, shallow waters with abundance of aquatic vegetation, and deeper places to which the fish can retreat, are the most favorable conditions for carp, and it is in such places that they multiply fastest and obtain their most rapid growth. In the hilly eastern part of the United States localities of this kind are relatively scarce, but the rivers and lakes of the Southern and Middle States, with their extensive bayous and marshes, come very close to the ideal conditions. This suitability is abundantly evidenced by the rapidity with which carp have taken possession of them, and have become in them, it might almost be said, the dominant piscine type. Nevertheless they are by no means confined to these waters which meet their requirements to the best advantage, but seem to be able to adapt themselves to a variety of conditions, though with less success. Thus we find them invading to a certain extent the colder and deeper waters of the Great Lakes, though a few fathoms is a great depth for them, and I have no evidence to show that they go to any extent into the deeper waters. They will live in small ponds fed by springs, where the temperature of the water always remains very low, but in such places their growth is slow and they are by no means so prolific as in warmer waters. On the other hand, they may sometimes be found living in mudholes, where it would not seem that they could obtain enough food for existence and where the temperature must at times in summer become comparatively high. They will live, and apparently do well, in waters that are strongly mineral. I saw, for example, a carp pond in northern Ohio

fed by an artesian well so heavily charged with sulphur that what appeared to be free sulphur was deposited in the wooden trough which conducted the water from the pipe to the pond. It is said that they even occur in abundance in the brackish or semibrackish waters of the Atlantic coastal region (Townsend, in "Discussion on Carp," Transactions American Fisheries Society for 1901, p. 117); and Day (1880–1884, p. 163) states that "a considerable number are taken in the Black Sea and Caspian; and Nordmann remarks upon their presence in the salt lakes of New Russia."

SIGHT.

Although carp work about in muddy, roily water, the roiliness being due largely to their method of feeding, they have, nevertheless, a quick sight, which serves them well when the water is clear. As will be discussed more fully under the subject of hearing, many actions which have been attributed to that sense are in reality dependent upon sight. Not only do they take fright easily at anything which moves, but there can be no doubt that they are able to recognize unusual stationary objects as well. I have often stood quietly for long times where the water was clear and carp were feeding on all sides of me only a short distance away. But when a fish came in my direction, it seldom approached closer than seven or eight feet, and usually not so close, before it would take fright and dash suddenly off. On the other hand, I have sometimes stood in roily water when they would actually bump into my legs before they would turn with a splash and dart away. At one time I built a scaffold some seven feet high above water in order to be able to overlook a wider circle of marsh. It was on the edge of a large spawning ground of black bass, and although a bass which was guarding a nest not far from the base of the scaffold soon became accustomed to the unusual structure and resumed his domestic duties, few carp came in sight, in spite of the fact that I sometimes remained quietly there for an hour and more at a time. When they came within a circle which would be traced by a line at an angle of approximately 45° from my position to the water, they apparently became frightened, and left suddenly.

In attempting to study the behavior of the fish at night, I at another time employed a powerful acetylene searchlight, such as is manufactured for use on launches. But this seemed to frighten them, even when 4 or 5 rods away. As the beam of light was swept around to different points I could hear the carp dash away through the rushes, and could sometimes see the disturbance they caused in the water, but in no case was I able to get close enough to see the fish themselves. Common experience in fishing at night with a "jack" shows that many kinds of fish are not so frightened by a sudden strong light.

That sight plays an important part in the feeding of carp may

readily be seen by the way they sometimes immediately take food thrown into the water before it has a chance to settle to the bottom. I have made no experiments to test accurately the sense of sight in carp.

HEARING.

It has always been a widespread opinion among carp culturists and fishermen that these fish are quick to detect and respond to ordinary sounds, such, for example, as the human voice. It is well known that pond fish regularly fed at a particular place soon learn to congregate at that place to receive their food. Many such instances have been recorded not only for carp, but for gold-fish, trout, and other species. As an illustration of the popular belief, which was apparently as prevalent in this country as in Europe, I may quote the statement of Mr. S. W. Coffin, given by Smiley (1886, p. 696):

> The sound of my voice is sufficient to bring them to the surface of the water, and a whistle causes them to come for food. For this they scamper through the water like so many pigs. They disappear as suddenly at the voice of a stranger.

Seeley (1886, p. 98) says:

> The hearing of the carp is excellent, and there are many examples of their answering a call; and it moves by hearing even when it cannot see. It makes an audible sound in eating and in swallowing air.

Fishermen, both here and abroad, are very careful to make as little noise as possible as they set their nets around a school of carp in the open or prepare to seine them from a pond; but when the net is set and it is desired to drive the fish into it they splash the water and shout to make all the noise they can.

Parker (1903) has recently investigated this sense in a few fishes and has given a general discussion of the subject. Since then Bigelow (1904) has done the same for the gold-fish; and since this last is such a near relative of the carp, we may be reasonably certain that the conditions in the two species are much the same. The experiments of these authors show without doubt that certain fishes, including the gold-fish, and so we are safe in assuming also the carp, are capable of hearing sounds produced in the water, or which are transmitted directly to the water, such as striking the side of a boat with an oar. I have had opportunity to see evidence of this in the field myself. By paddling quietly and carefully I have been able to work my boat into an open area in a pond where carp were present in numbers without disturbing a fish, when a sharp blow against the rail of the boat with the paddle would send them scurrying into the rushes in all directions. In this case, however, other vibrations besides sound waves are transmitted to the water which the fish might perceive by the sense of touch, so that such an experiment could not be considered as conclusive evidence that the fish heard the sound. This complication was obviated in the experiments of the authors mentioned above by the

use of an electric tuning fork giving a certain number of vibrations per second, which was placed against a board end of the aquarium in which the fish were being tested.

On the other hand, most fish "appear to be unaffected by loud talking or other like noises originating in the air" (Parker, 1903, p. 45), due undoubtedly to the fact that the ordinary sound waves produced in the air are transmitted to the water to a very slight extent at most. Several years earlier Kreidl (1896) had performed certain experiments on trout in the fish basins of the Benedictine Monastery at Krems, Austria, where the fish were called up to be fed at the ringing of a bell. He found that the fish appeared just the same if a person went to the customary place without ringing the bell, and that no amount of bell ringing would bring them if the person remained out of sight. On this account Kreidl concluded that fish could not hear at all. That sight is the important factor in the assembling of gold-fish to be fed was suggested by Seeley (1886) some ten years before, though he credited them with the ability to hear as well. He says (p. 112):

> Their sense of sound is sufficiently acute to obey a familiar call. The Chinese are said to assemble them in ponds at feeding-time in this way; but in ponds where visitors feed them in Europe they presumably detect the newcomer by sight; for we have noticed that a gathering never fails to greet visitors on their appearance at public gardens in which these fishes are exhibited.

From all this it appears that while fishermen, when desiring not to frighten the fish, need to be careful not to make disturbances which are transmitted directly to the water, such as splashing, or jarring a boat or similar object partially submerged, they need have little fear of talking; while, conversely, shouting probably has as little effect in helping to drive the fish, when that is the result desired. This fact will probably be received with satisfaction by those anglers who believed it necessary, but found it onerous, to maintain a sphinxlike silence while trying to outwit their finny prey.

TASTE AND SMELL.

As a matter of convenience these senses will be considered together. Of the two in fishes the former is much the better understood. Herrick (1903) has recently made an important contribution to the subject, besides giving an excellent review of the literature. It has long been known that carp have sense organs, known as "terminal buds," over the whole surface of the body and on the barbels, similar to those which occur abundantly in the mouth, and to which the sense of taste has rightly been assigned. Direct physiological experiments have not been made on carp, but from his experiments on a large series of other fishes Herrick concludes (p. 266) that—

> It may be regarded as established that fishes which possess terminal buds in the outer skin taste by means of these organs and habitually find their food by their means, while fishes which lack these organs in the skin have the sense of taste confined to the mouth.

Terminal buds, or taste-buds, outside the mouth are best developed in bottom-feeding forms and those which, like the carp, burrow into the mud for their food. They probably enable a carp to determine the presence of food material in the mud without actually having to take the mud into the mouth to test it.

What part the sense of smell plays is not so well established, though from the experiments that have been made on other fishes it would appear to be of minor importance and to be of little value in a directive way in the finding of food. In many fishes, however, it appears to enable them to detect the presence of food when it is in the immediate vicinity.

The tactile sense is well developed. How far carp can detect slight movements of the water, a faculty attributed by Parker (1903) to the lateral line, has not been determined.

MIGRATIONS.

The word migration is not used here in the strict sense of a regular and stated movement from one place to another, such as occurs in the salmon, shad, suckers, and many other species that ascend rivers and streams to spawn. The only habit of the carp which can be compared to this is their retreat to deeper water with cold weather and their return to shallower water with the coming of spring. Their movements at other seasons appear to be irregular and probably depend upon local and variable conditions. In ponds and other small bodies of water such migrations are necessarily limited, but may be much more extended and noticeable in large bodies of water such as the Great Lakes.

Some attempt was made to study this question in Lake Erie and the adjacent waters by liberating tagged fish and distributing a circular among the fishermen and fish dealers of the region, asking for the records of any of these fish that might be recaptured. A small copper tag bearing a number was attached, usually to the strong spine of the dorsal fin, by a piece of copper wire, though in a few cases the wire was passed through the basal lobe of one of the pectoral fins. This work was attempted only on a small scale at first, and later opportunity did not offer for giving it a more effective trial. Moreover, the method in which the carp are handled by the fishermen and in the wholesale houses made it very unlikely that the small tags would be noticed before the fish reached the retail dealers in far away cities, when it would be too late to get the desired data, even if the tags were returned. As it was, only about one hundred individuals were tagged and liberated, mostly in the vicinity of Port Clinton and Sandusky, and none of these was ever heard from again. As a consequence, direct observation and the results and testimony of the fishermen had to be relied upon for what information on this subject they

would give, and as the evidence gathered in this way was rather meager the question is still far from settled. Some of the observations are of much interest, however, and may serve to throw a little light on the subject.

A large proportion of the carp shipped from northwestern Ohio and southeastern Michigan are taken directly from Lake Erie. Many fishermen are engaged in the business, and they, for practical purposes, have had to learn much about the habits of the fish which furnishes them their livelihood. They go to the fishing grounds usually in open sail boats, returning to market when they have secured a good haul of fish. This means only a day's, or possibly two days', fishing when the carp are "on," but under unfavorable conditions the boats are often gone a week or more. The fish are taken for the most part by means of seines in shallow waters along shores. The methods of seining will be described more fully later (p. 611).

It is not surpising, in a body of water the size of Lake Erie, that storms should affect very largely, in fact we might almost say control entirely, the abundance of carp along the shore. According to the government chart, there is nowhere in the upper end of the lake more than six fathoms of water, while along the southern side water less than three fathoms deep extends to a distance of two to five miles off shore. Strong northwesterly winds are not infrequent during the summer months, and in the winter the principal storms are from the north and northeast. It does not take very high winds to stir such shallow waters to their depths, as is shown by the fact that even in moderate storms the water is made roily to a long distance off shore. At such times the carp apparently go out to the deeper waters, and the fisherman say they do not come in again until a day or two after the storm. Unfortunately the only data we have for determining the extent and character of these movements are the occurrences in the shallow shore water; we have little or no data for telling where the fish go when they leave. Pound nets in the vicinity of Niagara Reef, which is seven miles from the nearest land, and which were kept in operation all summer by a Port Clinton firm, did not help to throw any light on this question, since few carp were taken in them at any time. It is possible that during storms some of the carp leave the lake and run up the bays and rivers, and I am not convinced that such is not the case, at least with easterly storms, which raise the water level very appreciably at the western end of the lake. This produces a backward current up the bays and rivers, and evidence will be brought forward to show that carp run up the rivers with this back set. But storms from the north do not have this effect, while westerly winds lower the water rather than raise it. So while I think it not unlikely that many of the carp in the lake may enter the bays and rivers when there is an easterly wind, it seems that if this were

generally true with all storms, whatever their direction, it would surely be known to the fishermen, who utilize this movement of the fish in the river for their capture, as will be explained later.

As mentioned above, the water level at the upper end of Lake Erie is very variable. The long axis of the lake lies nearly west-southwest and east-northeast, so that both westerly and easterly winds have a great influence in piling the water at one end or the other. The prevailing winds of summer are southwesterly to westerly, so that the level is almost constantly changing. This gives a great resemblance to tides, except that the changes are, of course, much less regular, and generally of less amplitude. A strong southwest wind, however, blowing steadily for a day or two, will lower the general water level in Sandusky Bay, for instance, a foot or more, while a long-continued storm may result in an even greater change of the level. As soon as the wind ceases, or shifts around to the opposite direction, as is usually the case in our cyclonic storms, the reverse current sets in, affecting the water for miles up the Sandusky and Portage rivers.

Just how far this variation of the water level and the consequent reversion of flow of the rivers influence the movements of the carp I am unable to say. This much, however, is certain. A fall of a foot or even less in the general water level means the laying bare of great expanses of marsh land, and the carp which were feeding over this area have to seek deeper water as that on the flats gradually becomes shallower. In this way they work into the smaller streams, and so into the larger creeks, and from these into the river. It is at such times that they are taken in large numbers in a seine which has previously been stretched across the mouth of the creek, as will be described more fully in connection with the methods of fishing (p. 613). The fish appear to be quick to appreciate the lowering of the water, for they begin to run out very soon after it has begun to fall. Conversely, they run up again and spread out over the marshes as the water rises.

This movement, which seems to depend upon the gradual lowering of the water in the shallow places, is distinctly different in nature from the ordinary reaction of most fishes to a current of water. As is well known, most fishes, when placed in running water, immediately react by turning head-up into the current.[a] That this is true of young carp, I have ascertained by experimentation. It may also be the explanation of the crowding of these fish around the inlet when fresh water is being pumped into a pond, a phenomenon which will be described more fully in the discussion of their reaction to fresh water (p. 560). It is equally true that most fish become uneasy as the water in a vessel or other container is gradually lowered without producing a definite strong current. It is probably this "uneasiness" which causes the fish to leave the marshes as described above.

[a] For a discussion of the orientation of fish to running water see a recent paper by Lyon (1904).

As to the movements of the fish in the wintertime, when the rivers and bays are frozen over, I have no information. That they are in the deeper parts there is no doubt, and it seems likely from what I can learn from the fishermen that they must move about more or less even during the coldest weather. They are occasionally taken in numbers at this season, I am told, by means of a seine hauled under the ice.

It will be seen from what has been given above that, although they apparently do not have any regular and definite migrations, carp do make considerable movements dependent upon the conditions under which they live. It was at one time thought there might be some evidence to show that in Lake Erie the carp were coming to make a rather regular migration into the deeper parts of the lake with the approach of cold weather. The lake grows deeper to the eastward, and this would mean a general movement to the eastward in the fall and to the westward again in the spring. This habit in time might become established into a definite migration. But though the fish do undoubtedly seek deeper water in the winter, they probably go only far enough to escape freezing and the effects of storms. So long as they both feed and spawn in shallow water there is no other need for a migratory habit, unless perhaps the overpopulating of the more favorable waters may force some of the fish to seek new grounds. Reports of large schools of carp at times seen toward the eastern end of the lake seemed to lend some support to this view. Thus I was told by Mr. Crangle, a fisherman in Cleveland, that some time in July, 1901, large schools of carp were seen in the open lake. In near shore were small fish, while farther out were schools of large ones, which were noticeable from their swimming about with their dorsal fins out of water. Mr. Crangle says this was the first time carp had been seen in this part of the lake in such numbers; and he was certain of the identification, because his tug was run right in among them. Prince (1897) maintains that the carp has an inherent nomadic tendency, and thinks it is owing to this, in large part, that it has gained such a wide distribution. He says (p. 33):

> German carp are nomadic in their habits, and wander apparently aimlessly into all accessible waters, hence if introduced into any streams or ponds adjacent to and connected with others, these fish will rapidly spread over the whole system. Salmon, trout, white-fish, pickerel or doré, indeed all our native fish are more local in their wanderings and as a rule have definite courses of migration, and confine themselves within recognized limits. The German carp has no such defined movements or habitat, thus Lake Erie, the St. Clair waters of western Ontario, Lake Huron and other Canadian areas are being overrun by these fish, which have wandered from the more or less remote localities in United States territory where they were originally planted. Like undesirable weeds they spread everywhere and it is practically impossible to limit their progress or to effect their extirpation.

REACTION OF CARP IN PONDS TO INFLOWING FRESH WATER.

This reaction, which is very curious and marked, I am uncertain whether to consider a reaction to the current caused by the inflowing water or a response to the volume of fresh water being added to that which has been standing in the pond. Hessel (1881, p. 879) says:

> The inflow of water into the pond should never be allowed to be direct; as, for instance, a brook falling into it. This often causes the water to rise at an inopportune time, carrying into the pond other fishes, especially the rapacious pike. *The carp also has the disposition to swim toward the inflowing water, by which means it is drawn away from its proper feeding-places.*[a]

This matter was first brought to my attention in a practical way by Mr. Thomas Hurrell, who owns a carp pond near Port Clinton, Ohio. This pond covers an area of some 20 acres, or more, of marsh land beside the Portage River. A deep cut was made along the riverside and embankments thrown up on three sides so that it is possible to keep the water level two or three feet above that of the river, the fourth side of the pond being formed by the natural slope of the land. The water is maintained at a nearly constant level by pumping in fresh water, as necessary, from a dredge-cut just outside the embankment which leads from the river. The water is really elevated by means of an endless-chain elevator. This is shown in figure 2, plate III, while figure 1, plate III, shows the chute which empties into the pond. At this place the water in the pond is some 8 to 10 feet deep, and directly from it leads the deep ditch along the riverside, while shallower ditches lead off into other parts of the pond. (See figure, p. 628.) Mr. Hurrell said that scarcely has he started the elevator when the fish begin to come from all parts of the pond and to congregate in the deep area where the fresh water pours in. His account of their quick response seemed almost incredible, and I expressed a desire to see the thing myself; at which Mr. Hurrell kindly started the gasoline engine operating the elevator, and at once a good stream of fresh water began to be poured into the pond. I was subsequently fortunate enough to witness the phenomena I am about to describe on several different occasions. The following account is taken with little change from my notes of one time:

At the time of which I am speaking, a number of carp could be seen swimming about in the vicinity of the pumping house with their backs out of water. Mr. Hurrell attributed this to the fact that he had recently been pumping, and that the fish had not all dispersed as yet. He now started the engine again, and within five minutes the carp began to congregate in numbers in that vicinity, and they could be seen coming far down the large ditch, as many of them swam with their dorsal fins above the surface. The water near the inflow was soon full of them—it seemed as if there must be a number of tons of fish right

[a] The italics are mine.

there. They worked continually up toward the chute, where the water poured in, heading for the most part in that direction, but turning and twisting slowly about. They became so numerous after a time that the upper ones seemed almost forced out of the water, and many were turned over on their sides at the surface. Figure 4, plate III, shows a nearer view of the writhing mass of fish, all struggling to get nearer to the source of incoming water, though their movements appear rather slow and deliberate. Here it will be noticed that some of the fish are turned on their sides, and by the exposed backs it can be seen that they are nearly all headed in the same direction—to the right in the photograph. It was impossible to estimate the number of fish; there was no way of telling, in fact, whether they were mostly at the surface or whether they were as numerous deep into the water. I found, however, that at a distance of 20 to 30 feet away, where few backs were to be seen at the surface, an oar could not be put down into the water without hitting fish. Before long those nearest the chute began jumping out of water, some jumping to a height of nearly 2 feet into the air. Others made a jump and swam up the chute against the current as salmon leap a waterfall. Most were able to get up here but a short distance, while others worked up the whole length of the chute, some 6 or 8 feet, to the elevator itself.

From the actions of the fish in the vicinity of the inflow it seems as though they must be reacting to the current. There is no direct evidence that the response is anywhere to the fresh water and not to the current, as it is evident that to any part of the pond where the fresh water comes so as to influence the fish there must necessarily be some current. The part that seems incredible is that it should so soon effect remote parts of the pond with sufficient strength to produce a positive rheotactic response on the part of the fish. It will be noted, furthermore, that if this is the correct explanation the response appears to be just the opposite of what has been given above for fish in the marshes when there is a change in the general water level of the river. There the fish ran with the current, spreading out over the feeding grounds; here they come against the current as far as they are able to come, and crowd about the inflow. What may determine the difference in the nature of the responses in the two cases I am unable to say.

HIBERNATION.

Most observers agree that during the cold months in the temperate regions carp seek the deeper holes in pond or lake, where they pass the season in a semitorpid condition. It is said that they assemble in circular groups with their heads together and pointed somewhat downward towards the mud. During this time they take no food, though they are said to decrease but little, if at all, in weight. I know of no

statement as to whether the respiratory movements are suspended, and I have myself had no opportunity to observe carp in this condition. When I visited Lake Erie in November, 1901, some carp at least were still moving about, as they were taken in small numbers daily in the pounds and gill nets set for white-fish. This in spite of the fact that the weather was very cold, with frequent snow squalls, though the lake had not yet begun to freeze. Examination of the stomachs of these fish showed, too, that they had been feeding, though in no case was there much food in the alimentary tract. This observation agrees with the statement of Brakeley (1889), who says that instead of hibernating with the nose in the mud for several months, as they do in Europe, in this country they do so only for a short time, if at all.

VITALITY.

Many instances have been reported to show the extent to which carp can resist cold. I can not do better than to quote a case reported by Smiley (1886, p. 676):

On the morning of January 4, 1884, 2,100 German carp were forwarded from Washington, by express, to Birmingham, Ala. Mr. F. L. Donnelly, a messenger of the Commission, proceeded by the same train to watch them on their passage and to take charge of them upon their arrival at Birmingham. The fish had been placed in the usual 4-quart tin pails, and packed in crates of 16 pails each. Each pail contained 15 carp.

Mr. Donnelly and the carp arrived at Birmingham at 1.30 a. m., January 6. The packages were left in the office of the Southern Express Company through the remainder of that night, but placed within 10 feet of the stove in order to prevent the water freezing. The thermometer indicated + 4° F. at the time of arrival. At 8 o'clock on the morning of the 6th Mr. Donnelly examined the condition of the fish, and in his official report dated January 14, says:

"I was greatly surprised to find every drop of water in the buckets frozen into solid ice, and all the fish apparently dead; but upon close examination of their eyes, I thought perhaps a great many of them were still alive, though frozen solid in the ice."

Mr. Donnelly thereupon courageously undertook to see if any of the fish could be saved. He procured the necessary laborers, four large tubs, and a supply of water. He then broke the ice from the small pails, transferring such as contained carp to the water. He states that "in this manner a great number of fish were soon freed from their confinement, and by constant working with them during the entire day we were able to save 1,300 fish." Although the thermometer continued to remain in the vicinity of zero, by careful management he succeeded in keeping the 1,300 fish alive until the 8th and 9th, when they were distributed to the applicants throughout the State.

The saving of 1,300 carp out of a lot of 2,100, under such circumstances, may be considered a very remarkable achievement.

Having prepared the foregoing statement from Mr. Donnelly's report, I sent a copy of it to Mr. L. H. Black, route agent, Southern Express Company, Montgomery, Ala., asking how far he knew the statements to be true. Under date of January 25, 1884, he wrote me in reply as follows:

"As route agent of the Southern Express Company, my duties call me to Birmingham. I saw the carp first on the morning after their arrival at Birmingham, and frequently during the day while Mr. Donnelly was at work with them. My opinion

is that this statement is correct in every particular. I give it from what I saw myself, and from information Mr. Donnelly gave me during the day while he was working with the fish."

Smiley gives another instance (p. 698). This is the statement of Dr. George Wigg, Clay Center, Clay County, Kans., and is as follows:

I have a German carp in my office that has been frozen stiff on 16 different occasions in one month, and yet each time resuscitation has been produced after the lapse of six hours.

Although known as cold-blooded animals, the internal temperature of fishes is normally somewhat higher than that of the water in which they are living. According to Knauthe (1896) the amount of this difference depends upon the condition of nourishment, and varies in the different races of carp. In the winter, when no nourishment is taken and the vital processes are mostly suspended, the temperature of the body becomes the same as that of the surrounding water, and Knauthe states that the crowding together at the bottom of such fish as the carp, tench, and barbel does not help to keep their temperature up, as is maintained by some authors.

The hardiness of carp in enduring low temperatures for a long time without serious result is sometimes utilized in shipping them, by placing ice in the water to keep the temperature down. The normal activities are then much reduced, the respiration is retarded, and the fish can consequently stand a much longer sojourn in a small amount of water than would be possible at ordinary temperatures. I am told that the fish packed in ice even at points in Illinois and northern Ohio are sometimes still alive when they reach New York, in spite of the fact that they are sent by freight. Townsend (1902 *b*, p. 677) says those in the top layers will live two or three days; those below die sooner. In this case, of course, they are out of water entirely, though the gills are prevented from drying and the fish are kept moist by the gradual melting of the ice.

Like many other hardy fish, carp can be kept alive out of water for considerable periods at ordinary temperatures if they are kept moist, and they are often transported for short distances by packing them in wet moss. In Germany it is said to be a common practice at such times to place in the mouth of the fish a piece of bread or cake soaked in brandy. The statement is commonly quoted, especially in European works dealing with the subject, that carp are sometimes packed in moss with the head protruding and are kept in this condition for weeks or even months (!), being nourished in the meantime by placing food in the mouth. As an example of what is often stated, the following may be quoted from Day (1880–1884, p. 160):

Pennant observes upon the following experiment having been twice made, of placing a carp in a net well wrapped up in wet moss, the mouth only remaining out, and then hung up in a cellar or some cool place, the fish being frequently fed with bread and milk, and often plunged into water. Thus treated it has been known to live above a fortnight, and grow very fat as well as lose its muddy taste.

Whatever may be the truth as to the above, it is certainly a fact that these fish can withstand much in the way of adverse conditions, and can live for a considerable period out of water so long as the gills are kept moist. When it is desired to transport fish from where they are caught it is usual for the fishermen merely to load them into the bottom of a boat when the distance is not too great. For longer distances by water they are usually towed in a live-car.

When the United States Fish Commission was distributing many thousands of young carp every year it became a matter of great importance to have some practical method that would be economical as well as efficient. The original plan was to send a few fish in a large milk can full of water, but this practice was expensive and unsatisfactory. Later it was found that the fish could be shipped long distances, requiring several days or a week for the journey, merely by putting them in small pails with only a little water. The usual method was to use 4 or 6 quart tin pails, in which were placed 15 to 20 young fish 2 to 3 inches long, with little more than enough water to cover them (see McDonald, 1882, and later reports of the Commissioner). This small amount of water is kept well aerated by the jostling of the pails in transportation and the movements of the fish. In fact, it usually becomes foamy, on account of the slime secreted by the fish. I have myself used this method with success in shipping young carp from Port Clinton, Ohio, to Ann Arbor, Mich., the fish being about two days on the way.

Although carp will live so long out of water if the gills are moist, or in a small amount of water well aerated, they succumb much more quickly to foul water—that is, to water not well aerated, and consequently charged with carbonic acid or unoxidized organic matter. Under such conditions they may usually be seen swimming about with their mouths at the surface, a circumstance that is always to be looked upon with suspicion by the owner of a carp pond, as it usually means that the fish will die unless the conditions are quickly improved. Carp are apt to do the same thing when the temperature of the water becomes too high. Of course this action must be distinguished from the normal feeding of the fish at the surface.

FEEDING HABITS AND FOOD.

Carp are frequently stated to be "essentially vegetable feeders." It seems to me better to say that they are omnivorous, for I know of no food substance which a carp can get into its mouth that it will not eat. Since it can not be considered in the ordinary sense a predacious fish, however, the animal matter which it can ordinarily obtain is limited largely to insect larvæ, small crustacea and mollusca, and other similar small organisms, so that the bulk of its food is undoubtedly in most cases vegetable. Carp are often compared to pigs in their feed-

ing, and the simile is not bad, for much of their food is obtained by rooting about in the mud. In soft muddy or marly bottoms one will often see numerous little pits and holes a few inches, or often more, in diameter, showing where the fish have been at work. In most of its feeding the carp works slowly and rather quietly, though persistently; but the rooting in the mud they often undertake in a more vigorous manner, twisting and splashing, and tugging at the roots of water plants. It is this that makes the water so roily, and anyone familiar with their habits can tell at once the presence of carp when they are feeding in this manner simply by the appearance of the water. Moreover, the freshly dug up stems and leaves of cat-tails, sweet flag, wild celery, and other water plants are often to be seen floating about, furnishing further evidence of the destructive work going on below. The extent to which the character of the aquatic vegetation is changed in this way will be discussed later, when we come to consider the economic aspects of the question. The fish probably dig up these plants mostly for the tender shoots and rootlets, but they undoubtedly obtain many smaller organisms from the mud at the same time. The barbels at the sides of the mouth, which are well supplied with taste buds, are probably of much assistance in helping to ascertain the presence of food particles in the mud. I have not been able to observe the process in natural surroundings, but judging from the actions of small carp kept in an aquarium, I should say that much of the mud is sucked into the mouth and further "tested" for food by the more efficient[a] organs there; if satisfactory it is swallowed, if not it is rejected. The fish will often take into the mouth in the same way particles floating in the water, some of which will be swallowed and others rejected in a manner similar to that described by Herrick (1903, p. 265) in the sea robin (*Prionotus carolinus*). In respect to the distribution of the organs of taste and the manner of feeding, carp would thus appear to be midway between such forms as the cat-fishes on the one hand, which have a well developed sense of taste over the entire body, and the sea robin on the other, in which taste is confined to the mouth.

Carp do not, however, do all their feeding at the bottom by any means. Where the water is shallow and clear they may often be seen swimming slowly about, skimming floating particles of food from the surface or working industriously along the stems of the water plants. At the surface they probably get small floating plants, insects or their larvæ, such as mosquitoes, May flies (or "June bugs," as they are popularly called along the lakes), etc., as well as the seeds of plants, and other substances which are dropped or blown into the

[a] Herrick (1903, p. 267) says that "the delicacy of the sense of taste in the skin is directly proportional to the number of terminal buds in the areas in question." In the carp these buds are especially well developed on the "palate."

water accidentally. In feeding at the surface the fish swim about with the anterior part of the head showing, the mouth partly above water, partly below. The mouth is continuously opening and closing, and a sharp sucking or smacking sound is often produced, much as is made by a pig with his head down in the trough.

Much of the carp's food is obtained by foraging along the stems of water plants, and it also often eats quantities of the plants themselves. Many of these stems are covered with a considerable growth of algæ, bryozoa, etc., among which live a variety of minute, and even microscopic, plant and animal forms. Such stems as float on the surface or lie in a horizontal position in the water can be gone over very easily, and sometimes this appears to be done in a more or less systematic manner, the fish beginning at one end and working gradually along to the other. In order to get at the vertical stems the fish often turn on their sides, when the mouth can be closely applied to the rounded surface. They were also often seen to take the end of a floating stem or leaf, such as a cat-tail leaf, into the mouth and then pull and tug at it vigorously. Even if they did not get off pieces of the stem in this way, they undoubtedly pulled off the algæ and other substances growing on its surface. In one case I noticed a fish swimming about with a piece of partially decayed stem sticking from its mouth, but whether it was finally swallowed I can not say, as the fish swam away out of sight with the stem still protruding.

Few records of the food of the carp in this country made from examination of the contents of the stomach and intestine seem to have been previously reported. H. Garman (1888) reported on one specimen from Broad Lake, Ill., soon after the species began to be found in the waters of that state. According to him the food "consisted of vegetation and mollusks, the former constituting two-thirds of the material in the alimentary canal, and consisting of dead leaves and seeds. The seeds were, as far as could be determined in a hasty examination, chiefly those of trees and weeds. Elm seeds, ragweed seeds, and the seeds of *Polygonum* were noted. The mollusca were partially thin-shelled clams with an occasional *Sphærium*, and partly snails, such as *Physa* and *Lioplax*. All the matter was apparently gathered from the bottom. No trace of crustacean or insect food could be detected."

In August, 1900, Mr. M. C. Marsh collected carp stomachs near Bellevue, on the Mississippi River, near Omaha, and from Maumee Bay and River near Toledo, Ohio. Apparently no detailed study of these collections has been made, but Smith (1902), in his report on food fishes, gives a few general data. He states (p. 120) that the food was found to be largely microscopic, and contained in what was apparently a mass of mud passed on into the intestine, where he thinks the digestion probably takes place. Portions that were recognizable

macroscopically were rarely seen. In a few cases fragments of the higher water plants (e. g., *Ranunculus*) were found in the esophagus, while from the color of the small amount of fluid contents it was believed that green algæ might have been eaten. In the Maumee River the carp fed constantly and largely upon whole wheat that had been lost in the river a season or two previous in a grain elevator fire.

From the foregoing it appears that a large proportion of the material found by dissection in the alimentary tracts of carp was of vegetable origin. Since this material is eaten in such quantities and is digested in its course through the fish, as is shown by observation, the natural supposition is that it serves as food. And such is the opinion of most writers on the subject. Nicklas (1884), however, who discusses at much length the question of the proper food for the "artificial feeding" of carp, arrives at a different conclusion. It is his theory that these fish should be fed on materials especially rich in nitrogenous compounds, and in this connection he says (pp. 1011, 1012):

> I have started my theory from the fact, which I know from actual experience, that the food of the carp is principally animal and not vegetable matter, and I find that in this I agree with most of the practical pisciculturists; but I differ from the views of Professor Nawratil (Oesterreichisch-Ungarische Fischerei-Zeitung, 1880, No. 35) when he asserts that carp, from their third year, live principally on fresh and decaying vegetable matter. This is contradicted by the experience that they are easily raised in ponds which contain but few plants, and by the circumstance that, if aquatic plants formed the exclusive, or even principal food of carp, vegetation would, in some ponds, be utterly destroyed in a few days after they had been stocked with carp, or at any rate in a couple of years, as carp are particularly fond of young shoots, which, by the way, show a pretty close proportion of nutritive matter [to animal food?]. Such an occurrence, however, I have never yet been able to observe, nor has it been observed by any other pond-culturist; whilst, on the other hand, it has frequently been observed that in carp-ponds vegetation becomes so rank and luxuriant that it has to be checked. As long as decaying vegetable matter has not been examined as to the quantity of nutritive substances contained in it, no opinion can be formed as to its suitableness for carp food.
>
> My own observations have taught that the carp only takes to vegetable food when absolutely no animal food can be procured. I have not yet been able to ascertain whether the carp actually eats and digests decaying vegetable matter, because all I have so far been able to observe has been that the carp often swallows such matter, but almost immediately ejects it again, perhaps after having devoured worms and insects clinging to such matter.

I can not help feeling that Nicklas's judgment is influenced by his theory. Although he may possibly be right as to the kind of food that will be most economical in putting a given amount of flesh on a carp in a given time, it nevertheless seems evident, as a matter of fact, that carp do under natural conditions eat a large quantity of vegetable food. If Nicklas had examined the contents of the stomachs and intestines of the fish he observed, he might not have concluded that they ejected even all of the decaying vegetable matter that they ate. While it is not probable that the actually decaying vegetable matter

contains a great deal of nutritive material for the fish, this does not dismiss the whole question of vegetable food, as Nicklas implies; and while he says that carp can be raised in ponds which contain but few plants, being fed, I suppose, on animal food, on the other hand I have seen ponds in northern Ohio, where carp were retained from spring to fall, which contained practically no natural food at all, the water being supplied from artesian wells, and where the fish were fed exclusively on corn, barley, etc., and young "sowed corn," the plants being cut when 1 to 2 feet high and thrown into the pond. I am not prepared to say that these fish grew as rapidly as they would have if fed according to Nicklas's formulæ. But this does not concern us here. The important point is that carp can live very largely, if not entirely, on vegetable materials, and that under natural conditions in our open waters plants and plant products form a very large share of their food. The bearings of this, from an economic standpoint, will be discussed later on, where will also be considered the question of the extent to which carp may be injurious to the spawn and young of other fish.

Susta maintained that of its own choice carp would first select animal food, a contention in which he was supported by the observations of A. Fritsch in Prag and Emil Walter in Trachenberg. Karl Knauthe pointed out that these investigators had used exclusively the highly cultivated races, to which belong the so called Galician and Bohemian carp. He himself extended the investigation by comparing as to intestinal contents examples of the old Silesian carp and a new race of it bred by Gröger in Lauterbach with examples of the two quick-growing races mentioned above, using for the purpose fish of the same age. These fish, after each individual had been marked so that the four races could not be confused, were placed all in the same pool, which was rich in animal and vegetable food. In this way it was shown that the stomachs of the Galician and Bohemian carp were generally filled with small crustacea—chiefly *Daphnia* and *Cyclops*—as long as these were abundant, while insects and their larvæ were second only, in about the proportion of 3 to 1. Plant food was present only as it was taken incidentally with the other. In the cultivated Silesian carp the proportion of animal to plant food was about the same. The old Silesian "Bauernkarpfen," however, contained a great preponderance of vegetable materials, such as algæ, diatoms, plant débris, and the seeds of higher plants, and only a few animals, mostly small crustacea. As soon as the supply of lower animals in the pool was exhausted it became necessary for the Galician and Bohemian carp to adopt a vegetable diet as well. Moreover, Knauthe found the stomachs of these carp filled with a small species of pond snail which was abundant in the pool, and which both of the Silesian races spurned. From such and similar researches of Knauthe's it was shown that in

the spring the Silesian carp, though apparently well nourished, had reached a length of only 5 to 6 cm., while the Galician carp had grown to a length of 18 cm. The author answers the question, Wherein, under natural conditions, rests the ability for quick growth in fresh water fishes? by saying: "Partly, perhaps, in a better assimilation of the food, but mostly upon a better selection of the same. The richer this is in nitrogen, the greater, within certain limits, is its nutritive effect." (Zoologische Garten, Jahrgang 37, 1896, p. 345, 346.)[a]

In order to determine the nature of the principal food of the carp in this country I have examined the alimentary tracts of a great many individuals. Many of these examinations were not made in detail, but only to determine the presence or absence of certain things, such as the eggs of other fishes. A list of the contents of stomachs and intestines of 33 carp, however, is given below. These examinations were made with more care than the rest, but are for the most part only qualitative, the relative quantities of the various materials being given only in rough approximates. The carp were from several different localities and a variety of conditions. The list is given in full because it is believed to be important to convey a very thorough knowledge of the nature of the food of the carp in our waters. I have never found large particles of food of any kind in the alimentary tract, the largest being strips of vegetable epidermis perhaps an inch long, wings and other portions of insects, small snail shells, and the like. It is stated that carp can grind or "masticate" thin food to a certain extent with the flat, knob-like pharyngeal teeth, and probably this in part explains the fact that what is found in the stomach is usually so much broken up. Houghton (1879, p. 17) even maintains that "portions of vegetable food are returned to the throat and remasticated by these pharyngeal grinders," though I know of no evidence in support of this hypothesis. The finely ground condition of the stomach contents leads to some wonderment among the fishermen, who are accustomed in other fish to find the food, such as smaller fish, swallowed whole, and one man always insisted to me that carp "digest their food in their heads."

1. Specimen from St. Clair Flats, June 30, 1901. *Chara*, small amount; May fly (ephemerid) wings and broken fragments, considerable numbers; insect larvæ, small; roots, decaying leaves, and epidermis ("bark") of aquatic plants, large amount; small shells and fragments; sand. All the *Chara* seemed to be packed in the small intestine. This was noticed in other cases, and seems to indicate that when the fish get among the *Chara* they eat a large amount of it.

2. Specimen from St. Clair Flats, July 3, 1901. Rootlets and other vegetable matter, such as would be found in bottom mud; coleopter-

[a] For a more detailed discussion of the processes of digestion and assimilation in the carp, the reader is referred to a later paper by Knauthe (1898).

ous larva, small; algæ; fine shell fragments with fine sand or mud, forming a "grit."

3. Specimen from St. Clair Flats, July 13, 1901. Large mass of remains of Ephemerida, consisting for the most part of wings and of more or less broken up cercopods. (Fore wings 18 mm. long; one of the larger of the cercopods had 25 or 26 joints.) Very few other parts of the insects in evidence, except small opaque bodies with elliptical outlines, which were probably the eyes. The fact that the insects were adults would indicate that they were taken from the surface of the water either at the time of metamorphosing or when blown into the water later.[a] This one carp must have contained hundreds of these insects. Prof. R. H. Pettit, entomologist at the Michigan Agricultural College, kindly examined the remains of these May flies (or "June bugs") for me, but was unable to determine the species from the material in hand.

4. Specimen *45 cm.*[b] long from North Bass Island, Lake Erie, July 19, 1901. *Chara*, considerable; copepods and ostracods, numerous; *Chironomus* larvæ or related forms; fragments of shells (mostly quite small), considerable; plant fibers.

5. Specimen *27 cm.* long from North Bass Island, Lake Erie, July 19, 1901. Mass of food quite well digested. Much filamentous algæ (*Spirogyra* recognized) and diatoms.

6. Specimen *55.5 cm.* long from Put-in Bay, July 27, 1901. *Chara*, bulk of material, packing intestine full in places, mostly in small pieces less than 1 cm. long; May-fly larvæ, 1 to 1½ cm. long, large numbers; shells, broken pieces, and small bivalves 2 to 4 mm. long, entire; *Chara* and considerable other vegetable matter, some of it probably *Philotria;* mud, fine débris, evidently bottom sediment.

7. Specimen *33 cm.* long from Put-in Bay, July 27, 1901. *Chara*, mass of the material as in No. 6; amphipods, a number of small *Hyallela*-like individuals; broken shells, a very little; vegetable matter, a little besides *Chara*.

8. Specimen *38.5 cm.* long from Portage River, about 3 miles above Port Clinton, August 6, 1901. About 90 to 100 c.c. of rather fine, dark material, composed almost entirely of finely divided vegetable matter. A few filamentous algæ.

9. Specimen 50.5 cm. long from Portage River, as above, August 6, 1901. A considerable quantity of blackish "mud", vegetable fragments, pieces of stem, etc., the principal constituent; one pulpy mass, apparently an unopened bud of some kind, possibly "lotus" (*Nelumbo*) or water-lily; insect larvæ, occasional, head only recognizable.

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[a] On Lake Erie I have seen windrows of the cast pupa cases of ephemerids being drifted about by the wind, and extending as far as the eye could follow them. If carp could have got among these at the time the insects were leaving they would have had abundance of food for a time.

[b] Length of fish if in italics means total length—i. e., tip of snout to end of caudal fin; if in Roman type it is the length from tip of snout to base of caudal fin at middle.

10. Specimen 33 cm. long from Portage River, as above, August 6, 1901. Some 20 to 30 c.c. dark mud-like material, consisting mostly of plant fibers, fragments of stems, etc.; one young shoot (apparently of grass) about 18 mm. long.

11. Specimen 36 cm. long from Portage River, as above, August 6, 1901. Small amount of material of the appearance of fine mud; under the microscope seen to consist for the most part of finely divided vegetable matter and some filamentous algæ.

12. Specimen 47 cm. long from Portage River, as above, August 6, 1901. About 150 c.c. of material composed for the most part of vegetable matter—short pieces of stem, etc.; some pulpy vegetable matter, probably roots or bulbs of some aquatic plant; insect larvæ, occasional fragments.

13. Specimen 36 cm. long from Portage River, as above, August 6, 1901. Six to 8 c.c. of very fine material resembling mud in appearance, almost entirely composed of vegetable matter; vegetable fibers and some filamentous algæ recognized.

14. Specimen 44 cm. long from Portage River, as above, August 6, 1901. Only 2 to 3 c.c. of fine "mud", consisting of plant fibers, fragments of stems, etc.

15. Specimen 36 cm. long from Portage River, as above, August 6, 1901. Ninety to 100 c.c. of rather coarse dark material, mostly plant fibers and fragments; some pieces of leaves or stems 1 inch long, but most are smaller.

16. Specimen 32 cm. long from Portage River, as above, August 6, 1901. Small amount of very fine material. Most that is recognizable is portions of plant tissues—largely fibrous parts, and what appear to be the glumes of grasses.

17. Specimens 39 cm. long from Portage River, as above, August 6, 1901. Fifteen to 20 c.c. of dark grayish, almost black material, almost entirely composed of vegetable fragments.

18. Specimen 38 cm. long from Portage River, as above, August 6, 1901. Small amount of dark muddy material, mostly plant fibers and small pieces of other plant tissues; considerable filamentous algæ; insect larvæ (dipterous?), occasional.

19. Specimen 37 cm. long from Portage River, as above, August 6, 1901. Some 20 to 40 c.c. of fine, dark mud-like material consisting of vegetable fibers, fragments of stems, leaves, etc. Very little material in which vegetable cells could not be made out.

20. Specimen 34.5 cm. long from Portage River, as above, August 6, 1901. Fine material consisting mostly of filamentous algæ and partly digested tissues of other plants.

21. Specimen from "The Straits," 1 mile east of Cedar Point near Maumee Bay, August 12, 1901. Plants, pieces of stems, etc., considerable; algæ (filamentous), considerable; maxillæ of insects (?),

comparatively few; insect larvæ, few; diatoms; Vorticellæ; gastropods (?), few small fragments; much flocculent débris with small fragments of many kinds in it.

22. Specimen from Port Clinton, Ohio (from gill-nets in Lake Erie), November 16, 1901. Shell fragments, many, some of them 3 to 4 mm. in diameter; insect larvæ, fragments, caddis-fly (?) and some chironomid (?).

23. Specimen from Port Clinton (from Lake Erie), November 18, 1901. Shells, few small fragments; larvæ of caddis-fly (?), heads and other fragments; most of the mass of material appears to be made up of the nearly digested bodies of these larvæ. White-fish egg, one.

24. Specimen from Port Clinton (from Lake Erie), November 18, 1901. White-fish egg, one; larvæ of caddis-fly (?); entomostraca, mostly fragments; much of the material unrecognizable.

25. Specimen from Port Clinton (from Lake Erie), November 18, 1901. Shells, few fragments; algæ, few; apparently also other vegetable remains very finely divided; larvæ or worms of some kind, fragments; bulk of material unrecognizable.

26. Specimen from Port Clinton (from Lake Erie), November 19, 1901. Mostly fragments of *Chironomus* (?) larvæ.

27. Specimen from Port Clinton (from Lake Erie), November 19, 1901. Many remains of chironomid (?) larvæ (same as No. 26), much broken up; bulk of material unrecognizable.

28. Specimen from Port Clinton (from Lake Erie), November 19, 1901. Only small amount, about 2 c. c., in intestine; shell fragments; filamentous algæ; entomostraca, fragments, largely ostracods; caddis-fly (?) larvæ, much digested.

29. Specimen from North Bass Island (Lake Erie), November 27, 1901. Shells, 2 to 5 mm. in diameter, and shell fragments; ostracods, numerous, fragments of entomostraca in general.

30. Specimen from North Bass Island (Lake Erie), November 27, 1901. Shell fragments; entomostraca, fragments; insect larvæ, caddis-fly (?), fragments.

31. Specimen from North Bass Island (Lake Erie), November 27, 1901. Shell fragments, nearly one-half of material; ostracods, few; insect larvæ, caddis-fly (?), fragments; white-fish egg, one.

32. Specimen from North Bass Island (Lake Erie), November 27, 1901. Only a small amount of fine material, composed mostly of ostracods, Cladocera (?), and copepods, mostly fragments, some almost entire.

33. Specimen *46.4 cm.* long from Port Clinton (seined in Lake Erie), August 31, 1902. Principal material appears to be seeds of some sedge; aside from these the mass is largely fragments of plants and unrecognizable débris.

As to whether the fish were wont to feed most at any particular

time of day, I obtained no very satisfactory data. Neither did I find any other conditions which seemed regularly to influence their feeding. It is stated by some authors—and I have some evidence to bear them out—that carp feed especially in the early morning and late in the afternoon. But I have frequently found them feeding at all other times of day, even in the hot midday sun of summer. This much seems to be true, however, that they are usually more quiet in the middle of the day; one does not hear them splashing about so often. In the late summer, the fishermen tell me, the carp in Lake Erie, at least, feed mostly at night. As to the time of year, Seeley (1886, p. 97) says, "Like many other fishes, it feeds most frequently before the spawning season." In Europe they are said not to eat at all during the winter months. In this country I have reason to know that they do, to some extent, at least.

BREEDING HABITS.

In Europe the carp is said to spawn principally in May and June, though in some cases the process extends several weeks longer. As well as I can ascertain, the same statement holds for the northern United States. In our Southern States and California spawning is apparently earlier, often beginning in April. In the waters contiguous to Lake Erie the height of the spawning season seems to be in the latter part of May and early June. On the St. Clair Flats I believe it is usually a little later on account of the lower temperature of the water, which comes directly down from Lake Huron. This temperature difference affects the time of spawning of the bass, dog-fish (*Amia*), and other shallow-water spawners as well, for I have found the eggs of these fish at the Flats when the season for them was entirely past in the interior lakes and rivers of the state.

The age at which carp spawn also depends largely upon the temperature. European authors state that they reach maturity in the waters of temperate Europe when they are 3 years of age, and the same probably holds true in general for the corresponding region in North America, though apparently they sometimes spawn, at least in the latitude of New Jersey, when they are only 2 years old (cf. statement of John H. Brakeley, Bordentown, N. J., Smiley, 1886, p. 757). Judging from other statements quoted in the same report, they commonly breed at the age of 2 years in the South (where they do not hibernate in the winter), and according to Mr. Poppe, of California (Poppe, 1880, p. 664), his fish spawned when they were only 9 months old. At the time of first spawning the fish will usually weigh 3 or 4 pounds and have a length of 15 to 18 inches.

At the spawning season, but before the fish have spawned, the females can usually be readily distinguished by their distended condition. Though the ova themselves are rather small, the number is

very large, and the reproductive capacity of a carp increases greatly for the next year or two after it begins to spawn. According to Hessel (1881, p. 871) a female weighing 4 to 5 pounds will contain on an average 400,000 to 500,000 ova. Day (1880–1884, p. 161) quotes other estimates, thus: A female of 9 pounds had 600,000 eggs (Bloch); one of 16¾ pounds had 101,200, one of 25½ pounds 203,109 (Harmer); one of 21½ pounds had 1,310,750, and one of 16½ pounds had 2,059,750 (Buckland).

In the case of a female mirror carp from Sandusky Bay, which I weighed at Port Clinton June 22, 1903, I found that the ova comprised more than a fourth of the total weight of the fish. The fish before being opened weighed 17 pounds; after the removal of the ova with as little loss of blood as possible, the weight was 12 pounds 6 ounces, leaving 4 pounds 10 ounces as the weight of the ova. This is 27 per cent of the entire weight of the fish and 37 per cent (over a third) of the weight of the remainder of the fish after the ova had been removed.[a]

This enormous fecundity is undoubtedly an adaptation to compensate for the dangers of the exposed condition in which the eggs are left after being laid, since they are merely scattered about on the vegetation in shallow water and are given no further care or attention by either of the parent fish. It may also help to explain the remarkable increase in numbers of the carp in our waters in a very short time, for if we suppose that the ordinary enemies of the eggs were not in the habit of searching for food in the kind of locality utilized by the carp for spawning, or at least were not present in large numbers, it is easy to see what an advantage this would give the carp, especially if the conditions were favorable to its growth in other respects. Furthermore, it would not be at all surprising if, as has been known to have happened in other cases, the increase in the quantity of food furnished by the abundant supply of carp eggs would favor the corresponding increase of some other fish or other animal which finds the eggs good eating. Or possibly, even, some form which has previously lived on other food may adjust its habits to the new conditions, and come to prey largely upon the spawn of the carp. It will rather be surprising if something of the kind does not happen, for in their struggle for sustenance nature's creatures are no respecters of person nor property, and it would be an unusual thing for a rich supply of food to be lying around long without some of them appropriating it. When this does occur, the phenomenal increase of the carp will undoubtedly be checked and the natural balance will again be approximated. One thing that militates against this in the case of the

[a] Day (1880–1884, p. 161) says that continued cold weather may prevent carp from spawning, so that the process may last over several weeks or months, while some fish may retain the ova, thus occasioning disease. Bean (1903, p. 169) mentions that confinement of gravid females in a small tank may also cause them to retain the eggs, and he speaks of two fish that died from this cause.

carp and greatly reduces the danger is the short time required for the development of the eggs and the rapid growth of the young fish, which quickly takes them beyond the stage where they can be preyed upon by any but the larger of their enemies.

The general manner of the breeding of the carp is well known, but, so far as I am aware, the exact method has never been studied in all its details. This I found an exceedingly difficult thing to do in the open waters, where the opportunity to observe the proceeding is very largely a matter of chance. It is not so hard to find places where the fish are spawning, but the difficulty comes in getting close enough at the right time to see what takes place, and to have the water clear enough to see into when once close. These conditions I have never had the good fortune to have fulfilled, largely because the greater part of my work in the field has been after the spawning season of the carp was past. It is stated by many writers that at the time of spawning carp are so fearless, or at least so oblivious, that a person may approach very close to them and that they may then be easily captured (Hessel, 1881, p. 872). But I have always found even the breeding fish very shy. The place to make a careful study of the breeding habits would undoubtedly be in a moderately small pond, where the fish are confined to a limited area, and where they have become more or less accustomed to the presence of people in the vicinity. In the following description I shall rely for the most part upon my own observations, amplifying them where I can with the observations of others.

As is the case with the feeding, I could not ascertain that the spawning of the carp is confined to any particular time of day, though it apparently takes place more frequently in the morning hours. Hessel remarks that it is more frequent in warm than in windy and rainy weather, which agrees very well with my observations. At such times groups of fish may be seen swimming about at the surface, usually close together in a compact mass. In the marshes along the Sandusky River, where the best of my observations were made, the fish were in shallow water, one to two feet deep, and pretty well grown up with aquatic grasses, sedges, and flags, but with numerous open places from a few feet to a few rods in diameter, where the vegetation was not so abundant. The bottom was fairly solid, being composed of the roots of the plants and much dead grass. In these open places especially the carp could be seen, usually swimming slowly about with their dorsal fins and often a portion of the back projecting above the water. These also seemed to be the favorite places for depositing the spawn, though much is also deposited about among the thicker growth.

The spawning carp would usually be seen in groups consisting of one larger fish in the lead and a number of smaller ones following closely behind, making sometimes a string of six or seven fish in line, as is shown in the first figure on the next page. It is probable that

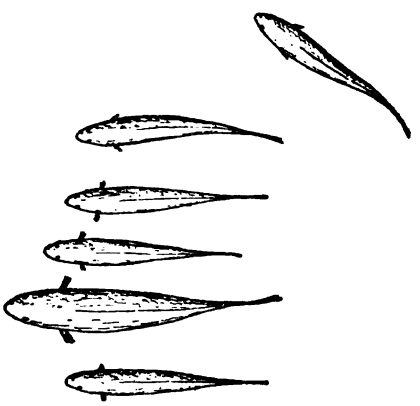
the larger fish ahead was a female and the others males, though I was unable to capture any of them at the time in order to confirm my opinion. This agrees, however, with the statement of Hessel (1881, p. 872), who says:

> Two or three or more of the male fish keep near the female; the latter swims more swiftly on a warm, sunny morning, keeping mostly close to the surface, followed by the males.

The Germans call this "streichen," or running spawning. Other writers agree in this matter, so I shall speak of the larger fish as the

Carp spawning. A female followed by a number of males.

female and the smaller ones as males, for convenience in description. As they go along, the males each appear to be crowding and pushing in to get as near to the female as possible, those behind often seeming to nose under and displace the ones ahead of them. This often gives the appearance of more or less of a struggle, and is accompanied by considerable splashing. After a time they come to rest, and four or five line up parallel to one another, as represented below, one or two males being each side of the female. They remain quietly in this way for a short time, perhaps one to two or three minutes, when one of them, presumably the female, starts forward and the others follow as before. While they are quiet, some of the fish of the group may not form in line with the others, but swim about in the vicinity, falling into line again as the procession moves forward.



Carp spawning. The fish at rest.

I was unable to tell at what moment the actual spawning took place, though I observed that at times one of the males would work forward beside the female until they were swimming nearly side by side, when he would turn somewhat on his side and bring his ventral side close under the female. At such a time the body of the male usually shook with a sort of quick vibrating movement (though this was not always observed to be the case), and it was then, too, that the most violent splashing of the water occurred. It is probably at this time that the eggs are laid and fertilized. Here again my

observations seem to agree with those of Hessel (op. cit.), who describes the process as follows:

They lash the water in a lively way, twisting the posterior portion of the body energetically, and shooting through the water near its surface with short, tremulous movements of the fins. They do so in groups of two or three males to one female fish, and forming an almost compact mass. This is the moment when the female drops the eggs, which immediately are impregnated by the milter.

To this he adds:

As this process is repeated several times, the female drops probably only from 400 to 500 eggs at a time, in order to gain resting time, so that it will require days and weeks before it has given up the last egg.

Among the earliest observations on the spawning habits of the carp are undoubtedly those mentioned by Walton (1901 ed., p. 116), which are interesting on account of their curious mixture of more or less accurate observations and quaint ideas. Walton says:

I told you that Sir Francis Bacon thinks that the Carp lives but ten years: but Janus Dubravius has writ a book *Of fish and fish-ponds* in which he says, that Carps begin to spawn at the age of three years, and continue to do so till thirty: he says also, that in the time of their breeding, which is in summer, when the sun hath warmed both the earth and water, and so apted them also for generation, that then three or four male Carps will follow a female; and that then, she putting on a seeming coyness, they force her through weeds and flags, where she lets fall her eggs or spawn, which sticks fast to the weeds; and then they let fall their melt upon it, and so it becomes in a short time to be a living fish: and, as I told you, it is thought that the Carp does this several months in the year; and most believe, that most fish breed after this manner, except the Eel. And it has been observed, that when the spawner has weakened herself by doing that natural office, that two or three melters have helped her from off the weeds, by bearing her up on both sides, and guarding her into the deep. And you may note, that though this may seem a curiosity not worth observing, yet others have judged it worth their time and costs to make glass hives, and order them in such a manner as to see how bees have bred and made their honeycombs, and how they have obeyed their king, and governed their commonwealth. But it is thought that all Carps are not bred by generation; but that some breed other ways, as some Pikes do.

It may be of interest to give one other account of the spawning, though it adds nothing in the way of accurate details. Nicklas (1886, p. 548) quotes the following from Horak:

The female fish, or spawners, accompanied by the male fish, or milters, move rapidly along the edges of the pond, or near the calm surface of the water. The actual process of spawning generally takes place during the early part of the forenoon. I have taken careful observations of this process, and have invariably noticed that several milters always accompanied one female fish, and deposit their spawn, for not all females spawn, at the same time. Sometimes this accompanying degenerates into a regular chase which lasts until the act of propagation has been consummated. At the beginning of the spawning season the fish therefore gather in large shoals and move so close together as actually to touch each other. During warm, calm weather the spawning process is carried on at so lively a rate that the water is squirted 50 to 85 cm. [20 to 34 inches] above the surface.

In another place Nicklas (op. cit., p. 523) says that in the artificial propagation of carp the spawning ponds "must contain some stones,

and in some places aquatic plants, because the female fish like to rub against stones for the purpose of ridding themselves of the roe"—a statement that I know of no observations to support; it seems much more probable that the eggs are extruded entirely by muscular action while the fish are swimming about.

In pond culture the breeding ponds are usually stocked with male and female fish in a definite proportion; the unit is technically called a "spawning party." Usage differs as to the relative number of each sex that is best for stocking a breeding pond, but it is customary to put in a larger number of females than males. It is usually planned that each "spawning party" shall consist of one "milter" and two "spawners," or else two "milters" are provided for three "spawners," while for each three milters is added one 3-year-old male fish, known as a "driver" or "enticer," which is "not used for spawning, but simply to drive or entice the other fish to that process."

According to Hessel (1881, p. 872), the male carp at the breeding season assumes a secondary sexual character which is common to many members of the family at that time, namely, a various arrangement of "protuberances, like warts," which are generally known as "pearl organs." In the case of the carp these are said to occur on the skin of the head and back. I do not remember ever to have seen them on a carp myself, and have no mention of them in my notes. If they are regularly present in these positions they undoubtedly function as Professor Reighard has found they do in other Cyprinidæ and some of the Catostomidæ, in helping to hold the female at the time of spawning—observations which have not as yet been published in detail (abstract Reighard, 1904). The method of the carp would seem to be much like that of the sucker (*Catostomus commersonii*), where the two males lie one on each side of the female, holding her firmly between them with the help of the pearl organs along the sides and tail.

Hessel also states that sometime before the spawning season sets in the pharyngeal teeth fall out and are renewed each year. On this point I have no observations.

The eggs are not laid in bunches or masses, but are scattered about in the water, and, being adhesive, they become attached to the roots and stems of grass and other aquatic vegetation, or to whatever objects chance to cover the bottom where they are deposited. The fate of the egg probably depends to a large extent upon where it chances to become attached, for should it fall into the mud there would be little chance for its further development. The eggs develop rapidly, but the time required for hatching depends very directly upon the temperature of the water. In temperate regions, under favorable conditions, they are said to hatch in about twelve days, though if the weather be so cold as to lower the temperature of the water it may take them sixteen or twenty days to reach their full development. In the warmer waters of

our Southern States the development is more rapid; in a pond in Georgia, when the temperature of the water was 69°, the eggs are reported to have hatched in five to six days, while the following year, with the water still warmer, the whole time consumed for development was but forty-eight to seventy-two hours (statement of H. H. Carey, M. D., Smiley, 1886, p. 687). The young fish also grow very rapidly and in the latitude of Lake Erie reach a length of 4 to 6 inches the first fall.

DISEASES, PARASITES, AND ENEMIES OF THE CARP.

The most remarkable fact in this connection seems to be that, although deformed and misshapen individuals are by no means rare, carp in the Great Lakes region appear to be very strong and hardy and almost free from diseases, whether such as are due to parasites or to other causes. This fact impressed me especially while I was working with them in the fish houses on Lake Erie, where I had a good opportunity to compare them with large numbers of other lake fishes. One finds intestinal parasites in almost any of the other species in great abundance, but in large numbers of carp examined I have found parasites in the alimentary tract in only one case. This was a rather large fish, which had some 16 round worms, nearly chrome yellow in color and 2 to 2.5 cm. (four-fifths inch to 1 inch) long, hanging to the walls of the intestine. Their spiny probosces were buried in the intestinal wall in true acanthocephalous fashion, and it required a considerable pull to detach them. These specimens were referred to Mr. H. W. Graybill, who studied the parasites of many of the Lake Erie fishes in 1901. Mr. Graybill reports that these are a form closely related to *Echinorhynchus proteus*, though he thinks they are possibly specifically distinct from that type. He further states that in 1901 he found in a carp a single dwarf specimen of the same worm.

Excrescences of the integument, probably caused by sporozoa, are not infrequent on the wall-eyed pike (*Stizostedion*), and were occasionally found on other species, but I did not observe them at all on carp.

In one case I found a leech attached to the base of one of the pectoral fins of a carp, but unfortunately the specimen was lost before it could be preserved, so that I have been unable to have it identified. The only Lake Erie fishes on which I observed leeches at all commonly were the lake lawyer (*Lota maculosa*) and some of the cat-fishes (especially *Ictalurus*).

There can be no doubt that the lampreys must also be considered among the external parasites of the carp, though I have never myself seen one attached to a carp. The fishermen told me that "lamper eels" were "common" up the Portage River, and I often found them among the fish brought to the wholesale house from both the river and the

lake. This was the so-called silvery lamprey, *Ichthyomyzon concolor*.[a] I inquired of the fishermen if they had ever seen the lamper eels attached to fish, and they said, "yes;" to the inquiry as to the kind of fish the reply was, "carp." On the 10th of August, 1902, I was assisting in making a seine haul of carp in the Sandusky River when one of the fishermen noticed a lamper "about 5 inches long" attached to one of the fish; it became detached, however, and escaped through the net before I could get to the place to see it for myself. Prof. S. H. Gage tells me that in his aquaria at Cornell University the young of the Cayuga Lake lamprey (*Petromyzon marinus unicolor*) have become attached to carp as soon as they were transformed from the larval stage and had left the sand. As carp are abundant in Cayuga Lake, as well as most of the other lakes in which this lamprey occurs, it seems very probable that during its free-swimming life the latter may be one of the important enemies of the carp, as it has been found to be of many other fish (Surface, 1898). In fact, Surface (p. 212) includes carp among those fish he has found dead with the marks of the lamprey on them.

Finally, under unfavorable conditions carp, like other fish, are susceptible to the attacks of fungus growths. So long as the water is pure there seems to be little danger of this, for I have seen carp that had been penned for long times whose heads were much bruised and abraded, but which were free from fungus. On the other hand, some young fish which I attempted to keep in an aquarium at Ann Arbor were soon attacked by a *Saprolegnia*, and I was unable to keep them alive for more than a few weeks on that account. The usual treatment with potassium permanganate and by immersing the fish for a short time in strong brine afforded only temporary relief. Smiley (1886, p. 754) gives the following with regard to carp attacked by fungus:

Statement of B. E. B. Kennedy, Omaha, Douglas County, Nebr., April 14, 1883.

FUNGUS.—On visiting our fisheries yesterday I find that many of the young carp are affected with a kind of parasite or fungus, which proves fatal. With some it appears on the back, some will have a strip nearly around the body, and some about the fins and tail. This fungus is easily removed, and the skin or flesh under it has the appearance as if the spot had been blistered. Several hundred have already died, and many more are similarly situated, and, unless there is some remedy administered, all will be likely to die. We have separated the affected ones from the others, hoping to stay the spread of the disease, if it is one. Those that show no fungus appear all right and take food readily.

NOTE BY PROFESSOR BAIRD ON FUNGUS.—When the carp are taken from their winter quarters for our spring shipments there seems to be a general tendency to the development of the fungus. It is probably due to the abrasions produced in handling,

[a] In color these specimens agreed more closely with the description of *Ichthyomyzon castaneus* Girard.

the development of fungus taking place in consequence of the emaciated condition of the fish after wintering. We do not find this diseased condition in the fish taken out of the ponds for the fall and winter shipments.

I am at a loss what remedy to suggest. It is possible that you may be able to destroy it by immersing the fish for a few seconds in a brine, of course allowing them to remain but a short time, and repeating the bath several times at intervals sufficient to allow the fish to recuperate from the shock of the operation.

According to European writers the carp in Europe apparently does not enjoy the wonderful immunity from parasites and from diseases that it does in our waters. A few quotations will suffice to make this clear. Seeley (1886, p. 98) says that in nature the carp lives 12 to 14 years, but survives much longer in confinement, though "subject to many sicknesses, deformities, and wonderful variations." Veckenstedt (1880, p. 673) remarks that diseases occur mostly to young carp; "polypes render the fish unfit for its full development; tape-worms constrict its intestines, make it lean, and finally kill it; lice torment it, and produce dropsy." And on this subject Day (1880–1884, p. 162) writes:

[It] is subject externally to fungoid growths, especially old carp; also the same mosslike appearance occasionally attack young fish which reside in foul or snow water, as well as blindness, epidemic fevers, visceral obstructions due to over-gorging on chickweed, ulcerations of the liver, malignant pustules under the scales termed small-pox by fishermen, carbuncles, and intestinal worms.

This difference on the two continents is probably in large part due to the fact that the carp described by the European writers were mostly fish whose ancestors for generations back were pond-raised fish, and which, owing to their long domestication, were more susceptible to the attacks of parasites and disease. These authors do not state what is the condition in the fish of the open waters of Europe in comparison with those reared in ponds, except Seeley's statement that carp kept in confinement are more subject to "sicknesses, deformities, and wonderful variations." Neither do we know the condition in this respect of those fish imported to the United States; hence it is difficult to say whether the apparently almost complete immunity of the Lake Erie carp is due to the fact that the fish originally brought to this country were practically free from parasites, so that few have been handed on to their descendants, whether it is due simply to the free, active life of the fish, or whether there is something peculiarly favorable to the fish in the conditions of our waters. The last seems to me likely to be the most important factor—that the conditions which have allowed such a phenomenal increase in the numbers of the fish have produced a hardy strain which is more than ordinarily resistant to the diseases that normally attack the species.

Professor Prince, commissioner of fisheries in Canada, makes special point against the carp on the ground of its susceptibility to diseases and parasites, and in a paper in which he strongly urges Canadians

not to undertake its culture he has the following to say on this subject (Prince, 1897, p. 35):

German carp are especially subject to parasites and contagious diseases. From their omnivorous and lethargic habits no fish are so readily attacked by diseases and parasites as carp. The "fish leprosy," described by Blake as a fungoid growth which spreads over the whole skin, turning the fish white and rendering it most unhealthy and a source of disease to all other fish, is essentially a disease of the German carp. Frank Buckland studied some of the diseases of these fish, and among others enumerated one malady which he called small-pox in the carp.[a]

Tapeworms and other disgusting endo-parasites occur most plentifully in carp. One described by Harrington Keene taken from a carp of 16 pounds weight measured no less than 45 feet in length. Of all fresh water fishes the German carp are the most subject to external and internal diseases. This is, in fact, unavoidable in a family like the carps, with sluggish habits, a fondness for coarse and loathsome food, and a preference for muddy and almost tepid waters.

If any of the above is from Professor Prince's own observations I feel quite certain that he can not, at all events, have made them in this country. And if the German carp in Europe has been found to be subject to a number of diseases and parasites, it must be remembered that this is a subject upon which comparatively little is known in general, and that the carp, being a cultivated fish, has afforded opportunity for close study which most others have not. Certain it is that some of the fungus diseases to which he applies such awful names will attack almost any fish or other water animal under conditions unfavorable to the latter, and especially if there happen to be any abrasions of the integument. The carp's hardiness in this respect is one of its chief characters, allowing of its cultivation in ponds and small enclosures, conditions under which many of our native fish would succumb to fungus and other diseases in a short time. Then, too, contagious diseases, strictly speaking, are, according to present knowledge, extremely rare among fish, and I am not aware that any has yet been found which attacks the carp. The whole tone of Professor Prince's paper leads us to suspect that if he were studying a fish malady he would call it by some such name as smallpox in carp, whatever title he might use to designate it in other species.

It remains now to consider certain enemies which menace the fish, especially those which may attack them while they are in the ponds. These are in reality very few in such ponds as are in use in this country, since the impounded fish are all adults, and the adult carp has comparatively few serious natural enemies. With the young fish it is different, and the regular carp culturist has, of course, to deal with all these factors. The eggs are exposed to a great number of dangers, and especially are they open to the attacks of minnows and other small

[a] The disease here referred to is apparently due to one of the Myxosporidia called by Hofer (1896, 1896*a*, 1896*b*) *Myxobolus cyprini*. This appears to be not uncommon in European carp ponds, but I am not aware of its ever having been reported on the carp in this country. I have not had opportunity to examine the recent handbook of fish diseases by Hofer (1904).

fish. It is a common statement, too, in books on the subject, that frogs are very destructive to the spawn and even to the young fish.[a]

Walton (1901 ed., p. 115) even believes that frogs sometimes attack the adult carp, and after speaking of the mysterious disappearance of carp from ponds, relates the following curious story in defense of his belief:[b]

And the like I have known of one that had almost watched the pond, and, at a like distance of time, at the fishing of a pond, found, of seventy or eighty large Carps, not above five or six; and that he had forborne longer to fish the said pond, but that he saw, in a hot day in summer, a large Carp swim near the top of the water with a frog upon his head; and that he, upon that occasion, caused his pond to be let dry: and I say, of seventy or eighty Carps, only found five or six in the said pond, and those very sick and lean, and with every one a frog sticking so fast on the head of the said Carps, that the frog would not be got off without extreme force or killing. And the gentleman that did affirm this to me, told me he saw it; and did declare his belief to be, and I also believe the same, that he thought the other Carps, that were so strangely lost, were also killed by the frogs, and then devoured.

And a person of honour, now living in Worcestershire,[c] assured me he had seen a necklace, or collar of tadpoles, hang like a chain or necklace of beads about a Pike's neck, and to kill him: Whether it were for meat or malice, must be, to me, a question.[d]

Among the other enemies to the young may be mentioned all the larger carnivorous fishes, turtles, water snakes, certain aquatic birds, especially the herons, and a few of the fish-eating mammals. Of the mammals, the only one that has to be especially guarded against in the ponds of this region is the muskrat, and that not because of any harm it does directly to the fish, but from the fact that it burrows through the embankments, causing leaks which may seriously lower the water level before discovered, and weaken the embankments themselves. Undoubtedly there must also be included among the enemies to the fish certain waterbugs, such as *Belostoma* (commonly known as the "electric-light bug") and *Ranatra*. An account of the ravages of these insects is given by Dimmock (1887), who quotes (page 69) the following letter, dated December 16, 1886, from Mr. E. A. Brackett, of Winchester, Mass. chairman of the Commission of Inland Fisheries of Massachusetts:

In October last, while drawing off the carp-pond, the water became very roily, and I noticed several young carp moving on the surface, sidewise, evidently pro-

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[a] Miss Mary C. Dickerson, of the Rhode Island Normal School, who has had much experience in keeping and observing our native frogs, has kindly sent me the following opinion as to the extent to which the North American species of frogs might prove injurious to fish ponds:

"Frogs would prove a menace to fish ponds, i. e., if in large numbers and if they were the aquatic frogs. We have only one in the East that would do any damage, that is *R. catesbiana*, our common bullfrog, although there is one other, *R. clamata*, that will feed on fish to some extent if there is not a large supply of air and surface-water insects. In the West *R. pretiosa* is wholly aquatic, i. e., it takes its food from under water. All of our other frogs (some 9 kinds) would be quite harmless. They spend very little of their time in the water and do not take food from below the surface. My conclusions are from several years of laboratory feeding experiments."

[b] In a paper which has appeared while the present report was in press Gill (1905, pp. 208, 209) quotes from other observations, which lend further credence to the belief that frogs, and toads as well, under the influence of sexual excitement, may attach themselves to fish in the manner described.

[c] "Mr. Fr. Ru." [Walton's original footnote.]

[d] Day (1880–1884, p. 162) quotes another and similar case from Pennant.

pelled by some external force. With a dip-net I took these young fish out, and found that in every case they were firmly held by a water-bug. The fish were dead, and the bugs apparently had been feeding on them. I had no means of determining how many of these bugs were in the pond.

Dimmock gives several references to literature on the same subject, and in the report of the United States Fish Commission for 1894 (1896, page 36) it is stated that carp in the ponds at Washington suffered from attacks of *Notonecta* and *Nepa*. As has been said, however, there is little to be feared from natural enemies in the temporary ponds and pens as they are conducted in this country, the greater dangers arising from impurity of water and other physical conditions.

ECONOMIC RELATIONS OF THE CARP.

Under this heading it is proposed to consider the relation of carp to aquatic vegetation, and to other fish and their spawn, as well as the secondary questions arising from these. The discussion is, for the most part, an examination of the numerous charges that have been made against the fish as to the damage it does, and in this respect is distinct from the succeeding chapter, which discusses the uses to which carp are and may be put. In Europe the mass of the literature on carp relates to its culture, but in this country it is safe to say that more has been written on the present subject than on all the others together. It has occupied our newspapers, our periodicals, and our scientific proceedings. Although so much has been written and said, however, this is nevertheless the subject on which perhaps the least is definitely known; the latter fact is probably an explanation of the former. Many extravagant statements have been made on the one hand as to the value of the carp, while on the other the English language has been searched to find words strong enough for its condemnation.

This state of affairs has, I believe, a very simple explanation. When the fish was introduced, the impression became prevalent that if one obtained a few carp, dumped them into any hole containing a little water which he chanced to have or could construct on his land, without further care he would always have a bountiful supply of excellent fresh fish. As recently expressed at a meeting of the American Fisheries Society, "almost every farmer had a carp pond in his front yard, back yard, or barnyard, or somewhere." These expectations were far in excess of what was ever claimed for the carp by its introducers, and it is little wonder that the people were disappointed. As it was seen that the ponds did not yield the phenomenal results expected, and as the novelty wore off, they were left neglected and uncared for, so that within a short time, through the agency of freshets and the undermining of embankments, the fish had gone to help stock the public waters in all parts of the country. For a time after this, comparatively little was heard of them, except that in local lists of fishes they grad-

ually began to be included as becoming common. But in many localities in recent years there has been an alarming decrease in the number of waterfowl, game fishes, and in many cases commercial fishes as well, and gradually the blame for much of this has been shifted upon the carp, which in the meantime has become the most abundant fish in some localities. Whether the blame was rightfully placed or not, remains to be seen. The game and food fishes seemed to be decreasing, the carp were undoubtedly increasing, and to many minds the inference was plain. It is a curious fact that those who are most concerned in the decrease of the fish and game are often the last to see that they themselves might in a measure be the cause. They are looking elsewhere for the explanation, and when a possible factor presents itself it is at once seized upon and made to bear the brunt of the whole charge. This is the point that I wish to emphasize here—that most of the statements that have been made as to the damage done by carp have been based upon very insufficient evidence; if founded upon direct observations at all, they were observations that, if not inaccurate, were at least inadequate. At best the evidence has been circumstantial, while on the other hand the defense has been either simply negative, or in places the attempt has been made to vindicate the carp on the grounds of its usefulness.

The denunciations of the carp have been so numerous, and in many respects so similar, that only a few quotations need be given to show their tenor. The specific charges based on direct evidence, so far as I have been able to find them, will be dealt with in more detail. What I shall attempt to do is to sift the evidence in as careful and impartial a manner as possible, adding to it what I have myself been able to learn in the prosecution of my studies on the subject. The best recommendation I can bring forward for myself as a juror in the case is that I approached the subject with little knowledge of the particular question, and, consequently, "unprejudiced and without previously formed opinions."

It should be borne in mind that direct observations bearing on the various phases of the question as to the damage done by a fish like the carp are very difficult to make, and are in most cases largely matters of chance, while at the least they require a great amount of time. Take for example the relation of the carp to the black bass. The question is often asked, "Will a carp drive a black bass from its nest and devour the spawn?" If a person by chance happens to see the thing done, and is certain that he has interpreted his observations aright, there is the proof of the matter, and so it is settled. On the other hand, one might watch a bass nest for a long period—say, many hours each day—and never see a carp come near it, but one would still have no proof that it might not do so—his evidence would be only negative. To be sure, the longer the observation was continued the greater would

be the probabilities in favor of the harmlessness of the carp; but it seems to me that in most of these charges of destructiveness the burden of proof must rest with those that make the charges. If, however, in the case supposed above, the watcher should see a carp come near and be driven away by the bass, this would be good direct evidence in the carp's favor. All this serves to emphasize the importance of taking advantage of whatever opportunity chance may offer to throw light on these questions.

The principal charges that have been preferred against the carp have been enumerated in a preliminary statement of the present investigation (U. S. Fish Commission Report, 1903, p, 129) as follows:

(1) That the carp thrashes about and stirs up the mud, so that the breeding grounds of other fish are spoiled; (2) that the carp roots up the vegetation, destroying the wild rice, etc., and thus ruining good duck-shooting grounds; (3) that the carp eats the spawn of other fish; (4) that the carp eats the young of other fish; (5) that the carp is of no value as a food fish; (6) that the carp is of no value as a game fish.

To the first of the above might be added the charge that in stirring up the mud of supply reservoirs of water that is used for drinking purposes the water is made unfit for use. The first four of the charges will be considered here, the fifth and sixth will be discussed in connection with the food value and uses of the carp.

RELATION OF THE CARP TO VEGETATION.

The principal complaint against the carp on account of its destructiveness to aquatic vegetation comes from sportsmen, especially the duck hunters. They are almost unanimous in their condemnation of the carp on this account, but conversation with a number of them soon makes it apparent that while some are speaking from personal experience, and the opinions given are their own, many are merely repeating statements which they have heard, and which have become so stereotyped that they are easily recognizable to one who is investigating the subject. It so happens that the St. Clair Flats, and more especially the marshes bordering Lake Erie, are among the most famous duck-shooting localities in the Middle West, so that in this connection I shall confine myself for the most part to inquiries made there.

The most definite information I obtained as to the changes that have taken place in the aquatic vegetation in the last decade or so was near the mouth of the Sandusky River, where it opens into the bay of the same name. Mr. Fitzgerald, the keeper at the Winnows Point Club, who has lived in the region all his life, not only told me of the changes in the conditions as he could remember them, but allowed me to examine the records of the club in further substantiation of his observations.

It appears that the first carp were brought to that immediate vicinity in 1883 by D. W. Cross and Colonel Scovill, of Cleveland. A small pond was prepared near the clubhouse and, according to the records,

on May 20 was awaiting the arrival of the fish. These probably came soon after and were put into the pond on or before the morning of the 21st, for on that day there was a severe storm, the pond was flooded and finally broke out at 2 p. m., and all the fish escaped. The lot consisted of 20 leather and 20 scale carp. Later a large lot of young carp were sent to the club and were liberated in the marshes by Mr. Fitzgerald's father, and still more were planted by a tug which went up the river, putting in carp at various places along the route. To-day these fish are extremely abundant in this locality, and have been so for a number of years.

According to Mr. Fitzgerald's statement, coincident with the increase in the carp there has been a great decrease in the amount of wild celery (*Vallisneria spiralis*) growing in the shallower waters. He says that formerly, in late summer, the strip of comparatively shallow water extending some quarter to one-half mile from the clubhouse to the main channel of the river was thickly grown up with this plant. Its leaves were so abundant, floating on the surface of the water, that it looked almost like a solid bank, and it was only with great difficulty that a boat could be paddled through it. To-day this stretch is open water; only here and there do a few lily pads come to the surface. Much the same thing had been told me the previous summer by a carp fisherman, who for many years has acted as guide for hunters in the region. He affirms that the marsh has changed greatly in the last few years, and believes it is due to the carp. He says the carp root up principally the wild celery (*Vallisneria*), wild rice (*Zizania*) and deer-tongue (probably meaning both *Sagittaria* and *Pontederia*); and that the "canvasback celery" (*Vallisneria*) has been largely cleared out.

At the same time the duck shooting is said to have been rapidly on the decline. The canvasbacks (*Aythya vallisneria*) and redheads (*Aythya americana*) especially have been growing scarcer and scarcer. The records of the Winnows Point Club, mentioned above, show a very marked falling off in the number of canvasbacks killed in about 1893, and conspicuously so in the numbers of both species in 1898–99. This is ascribed to the "absence of food." Since 1899–1900 not more than three or four canvasbacks have been killed by the members of the club each year. It is the custom now to sow wild-rice seed in the vicinity, but I do not know whether this has yet proved to be beneficial.

In order to learn something of the conditions and the sentiment of the sportsmen in the western part of Michigan, where there are many famous duck marshes, I sent a circular letter to the postmasters at Muskegon, Grand Haven, Holland, Saugatuck, and South Haven, and in each case received a reply either from the postmaster himself or from some one to whom the letter had been referred by him. The verdict from Saugatuck, on the Kalamazoo River, accorded very closely with that from Lake Erie. Mr. Charles E. Bird wrote that they have

no wild celery, but do have much wild rice. Since the carp have been planted, however, this has been largely rooted out; "they dig it up like a drove of hogs, and have about spoiled the marshes for ducks."

Mr. C. J. Dregman, of Holland, writes that carp are abundant in the lake (Black) and river there, and adds:

As to their destructiveness to wild celery or otherwise I have no reliable information to give you. There is comparatively little wild celery here, and that which does grow here seems not to be affected from year to year. Common report has it, however, that carp are destructive to fish eggs and nests.

Mr. George C. Monroe, of South Haven, does "not believe they cause any damage to plants along the river bank." At Muskegon, according to Mr. E. D. Magoon, "the marsh is full of channels and bayous, and these abound with carp." Wild celery, rice, and other duck food are found here, but he expresses no opinion as to the effect of the carp on these.

Considerable valuable testimony on the question under discussion is given by Doctor Smith in his report on the acclimatization of fish in the Pacific States (Smith, 1896, pp. 393–403). Several cases are mentioned where carp are reported as destroying the vegetation, most notable among which are observations made at what are known as the "Suisun Marshes." Doctor Smith (p. 397) quotes a letter from Mr. Ramon E. Wilson, secretary of the California Fish Commission, dated November 12, 1891, which states that certain portions of the marshes referred to above have been preserved by five shooting clubs for a period of ten years previously. The letter continues:

Each of these clubs has, from year to year, supplemented the natural and indigenous growth of vegetation by planting non-indigenous seeds and grasses, until about two years ago the ponds, ditches, and sloughs had so grown up with vegetable matter that upon the opening of the season it was almost impossible to push a boat through the dense growth. Last year, the season of 1890, it was discovered that a marked change had taken place. The cause was attributed to the winter, which was a rather severe one, in that there were many overflows and freshets occasioned by heavy storms. This year the change in the respect mentioned was much greater. It was early reported in the spring that there was very little sign of vegetable growth in any of the ponds. Investigation followed, and it was found that fish in large numbers, ranging from a few inches in length to 15 pounds in weight, had invaded the grounds and taken entire possession of all the waters. These fish came, say, in May and remained until about the latter part of July—that is, the bulk, but many remained later. We are convinced that these great numbers came to spawn. About August this great school, if you can so call it, suddenly disappeared—that is, the larger ones and the majority of the whole. Their going was not unlike the grasshopper in effect on vegetation—not a sign or remnant was left. The result is that to-day, where these same ponds have heretofore afforded unlimited food supply for surface-feeding ducks in the early part of the season and a like supply of celery bulbs for the canvasbacks and redheads for the balance of the season, there is absolutely not a single sign of vegetation. At the time mentioned I carefully examined the beds of the ponds and found them positively barren of vegetable matter. Notwithstanding the emigration, if it can be so called, of the larger fish, the waters are still alive with the same fish, ranging from 2 to 8 inches in length. These ponds, heretofore quite clear, are now nothing

more than mudholes. That this fish burrows in the mud there is no question. The beds of the waters are not unlike a sieve in appearance, with holes, round in form, ranging from one-half inch to 3 inches in diameter. The banks of the ponds and sloughs are quite like the bottoms. The fish have burrowed to the depth of a foot in many places, and it can be readily seen that it has been done for the purpose of getting at the roots of the vegetable growth.

That the fish which caused these disturbances were carp Mr. Wilson determined by sending specimens to Dr. David S. Jordan.

The testimony of Mr. John P. Babcock, at that time chief deputy of the California Fish Commission, is very similar. He is quoted as follows (Smith, 1896, p. 399):

The carp have destroyed almost all the wild celery of the lower Sacramento and Suisun Marshes. They reach all the ponds during high water, and, as soon as celery comes up, they eat the shoots, and, in many of the best ponds on the shooting preserves, have taken roots and all of the celery. They have not destroyed the tule grass to any noticeable extent, if at all. The damage has been to the better grasses. Many of the clubs planted wild celery in 1891, 1892, and 1893, but the carp destroyed it all, and it is claimed by observing men that the celery is entirely destroyed. The clubs resort every season to baiting their ponds with grain, and in these ponds the carp move in droves that W. P. Whittier tells me look like a tidal wave, as they move from one side to the other.

The most extravagant charge as to the damage done to vegetation by carp which I have seen is given by Prof. E. E. Prince, commissioner of fisheries for Canada, in a paper discussing "The Place of Carp in Fish-culture" (Prince, 1897). He says (p. 33):

In connection with this charge, a western United States paper tells of a rancher's visit to Portland, Oreg., to sue for damages he had sustained from the introduction of carp. He wished to find out whether he had recourse against the United States Fish Commission for the introduction of carp into the rivers of this section. He says these fish are destroying his meadows by eating his grass and grubbing up the roots. As the water overflows his meadow the carp follow it up in thousands, the small ones weighing about 3 pounds pushing their way up where the water is only 3 inches or so in depth and clearing off all vegetation, so that when the water recedes he will have mud flats in the place of meadows.

This statement appears the more credible, however, in view of some remarks made by Doctor Hutchinson, stationed at Portland, Oreg., in a letter discussing the value of the carp as an eradicator of the fluke disease of sheep. Doctor Hutchinson says (Stiles, 1902, p. 221):

All the bottom lands of this river [the Columbia] are subject to annual overflow, and at this time the carp clean the meadows as thoroughly as a fire. Every spear of grass, up to the very water's edge, will be eaten by them. They also have a habit of rooting all around the edge of this overflow as it gradually recedes.

Mr. Hessel, in reply to the letter from Mr. Wilson regarding the damage caused by carp in the Suisun Marshes (Smith, 1896, p. 400), states it as his opinion that the carp are in search of worms, crustacea, larvæ, etc., when they dig about the roots of the plants, and that the uprooting of the plants themselves is merely incidental. According

to him the aquatic vegetation in the Potomac River has not been damaged by carp, although these fish are abundant there. He says:

The carp is very numerous and prolific in the Potomac River. There are specimens from 20 to 30 pounds, but that they go for the water celery has not been noticed here as yet. Water celery grows in abundance in places where the river flows slowly, especially about the so-called flats, but any injury to its growth, or a reduction of its density, not to speak of its total destruction, has not been heard of, as far as I know, with two exceptions only, not attributable, however, to the carp, but to high water in the spring of 1882 and 1889, when every kind of vegetation was swept away by the floods, and consequently water celery disappeared from the river during the two years subsequent to those freshets.

I must not forget to call your attention to the fact that turtles, too, are not averse to a meal of water celery. Frequently I have seen "red-bellies" and "yellow bellies" feasting in the dense growth of Potomac celery upon that plant. Another point: For years I have kept quite a number of these species of turtles for ornamental purposes in a small pond about this station and fed them with water celery taken fresh from two ponds stocked with a great number of old and young carp, which never touched the celery, though it must be admitted they did loosen the roots in their hunt for animal food.

In conclusion, I reiterate that I am not familiar with the fauna of the Suisun Marches, but my impression is that, upon closer investigation, there may perhaps be found additional causes for the disappearance of the water celery and other vegetation therein, besides the undeservedly much-abused carp.

Even if Mr. Hessel's contention that the uprooting of the plants is a secondary result as the carp is searching about in the mud for animal food should be found to be true, the nature of the damage done would be the same. It seems, however, from the facts brought forward in the discussion of the food of the carp, that we should not be too hasty in concluding that it is altogether for animal matter that they dig up these plants; knowing as we do that they eat a large quantity of vegetable matter, it seems likely that they would take it whenever there is opportunity, so that in the case of the wild celery they probably eat the softer parts of the plant as well as the crustacea, insect larvæ, etc., dug up in the mud.

The fact that the wild celery in the Potomac was not being destroyed is a matter of more weight, but if the damage in other places is really perpetrated by the carp it merely goes to show that under certain conditions the fish does not harm the vegetation to a marked extent, while in other cases it does. This perhaps depends upon the relative abundance of other food. Furthermore, as Mr. Hessel suggests, there should be further investigation as to whether the carp is the sole factor in causing the rapid disappearance of these water plants. It must be remembered that we know very little of the obscure ecological forces at work which may cause great changes in the aquatic flora of a region. Since these reports come from such widely separated areas, however, the factor which is causing the destruction must be a very general one. If the damage were confined to the Great Lakes basin, for instance, it might be expected that some general phenomenon, such as a gradual

lowering of the water level in the basin, might be the cause, though it is difficult to see how that particular factor, even if it could be proved to exist, would effect the vegetation as has been observed. It would be expected as the result of such a lowering that the different floral zones would not in most cases be destroyed, but would merely reestablish themselves a little farther out from the original shores. Since a similar decrease is being complained of in many parts of the country, however, and within comparatively only very recent years, we would expect to find the same cause in all cases, and would look for some new factor coincident with the trouble. The planting and astounding acclimatization and propagation of carp seems to have introduced such a factor.

Then, too, there must be examined the more direct evidence against the carp. Vegetation has been rooted out of comparatively small ponds and reservoirs, where close observations could be made, and where apparently the only change in conditions that could account for it is the introduction of carp. And, finally, we know that these fish do root up many plants. In a pond where the carp were feeding in large numbers I have seen the surface of the water quite well covered in places with the uprooted vegetation, among which were to be seen whole plants of flags torn out bodily. In other places, when the *Vallisneria* was still young and did not reach nearly to the surface, I have observed the leaves floating about, recently torn from the bottom. Although it could not be determined with certainty in this case, it is very probable that carp were responsible. The roiliness of the water at the place served to strengthen the suspicion.

One can not be too careful, however, in drawing conclusions of this kind, since there are many opportunities to make mistakes. A concrete example may serve to illustrate the point. I was wading about in a little bay at the St. Clair Flats, where carp were abundant, and noticed many freshly torn up leaves of flags floating on the surface. It looked very much at first as if this were the work of the carp, but I later saw the agency at work--a muskrat, which dived to the bottom, cut off a leaf and brought it to the surface, floated there while he ate the succulent lower end, and then left it, to go down after another. These leaves were bitten off singly, however, while the flags mentioned above as uprooted by carp were torn up roots and all, probably not so much on account of direct pulling as by having the mud worked away from around the roots.[a] The male dog-fish (*Amia calva*)

[a] Unfortunately it was found inexpedient to make an experimental test of the effect of carp upon aquatic vegetation. This could be done by having two similar ponds or enclosures in which conditions are as nearly the same as possible. Into one of these should be introduced a certain number of carp, while the other should be left without them. If this were done in the spring, for example, an exact comparison could be made of the conditions in the two areas as the season advanced. The greatest caution should be taken in seeing that all conditions, except the presence of the carp, should be the same in the two enclosures.

also cuts off the young shoots when building its nest, and at such times these may be found floating on the surface of the water.

In conclusion, as to the relation of carp to aquatic vegetation, the evidence seems to be pretty strong that in general they are very destructive, and are probably, in large part at least, responsible for the great reduction of wild celery and wild rice that has been noted in many of our inland marshes in the last few years. This, in turn, has deprived certain ducks, especially the canvasback and redhead, of an important food supply, and has undoubtedly influenced their abundance to some extent in the localities in question. Whether the great reduction in their actual numbers can be laid to this cause is a very different question; and when we observe that the same complaint is being made of nearly all game birds and mammals not rigorously protected by law, it makes us look for an influence at work more general than the introduction of carp into our waters. Such an influence is to be found in the hunters themselves, and must be reckoned with in the case of the ducks as well as elsewhere. Whether it is more or less potent than the reduction of one of their sources of food is a question which remains to be settled. It is possible, too, that with the development of the country, and especially the opening up of extensive areas by irrigation, the ducks, instead of being actually so decreased in numbers as would at first seem to be the case, have scattered to new feeding grounds. A portion of the following quotation from the paper by Smith (1896, p. 399), mentioned above, refers to this possibility, while it also sums up in a concise manner the other aspects of the question:

> In attributing to the carp the scarcity of canvasback and other ducks in a given region, there should be proof that the carp does and other fish do not eat and uproot large quantities of *Vallisneria;* and the influence of market hunters and indiscriminate killing by sportsmen must not be overlooked. The scarcity of canvasback ducks in most streams probably antedates the advent of the carp in noteworthy numbers, and, as in the Potomac, was coincident with spring shooting and with the activity of pot-hunters using swivel guns. Mr. John P. Babcock, chief deputy of the California fish commission, states that he thinks ducks in that State have changed their feeding grounds; miles of land in the San Joaquin Valley are now covered with ditches and miles of alfalfa now grow where a few years ago there was a desert; and the main market supply of ducks comes from that region instead of the Suisun Marshes. He thinks, however, that the carp have proved very objectionable in this region.

In consideration of all the evidence set forth above, although we are obviously unprepared to say to what extent, we seem forced to conclude that carp are, in some measure, detrimental to certain species of ducks.

ROILINESS OF WATER INHABITED BY CARP.

The extent to which carp stir up the bottom mud and make the water roily has been mentioned in speaking of its habits, and especially its manner of feeding. As a general thing this is one of the surest indications of the presence of these fish in waters that would otherwise be

clear; and it has several rather important economical bearings besides the mere fact that it usually accompanies or is accompanied by the uprooting of the aquatic vegetation. The constant roiliness of a body of water that has theretofore been clear must be an important ecological factor in determining the quantity and character of both the vegetable and, at least secondarily, the animal life inhabiting it. This will readily be appreciated when we consider that it decreases the amount of light that would reach to any given depth, thus depriving plants at that depth of at least a part of one of the most important conditions for their growth, while in the second place the settling of the sediment upon the stems and leaves of the plants acts as a mechanical hindrance to the ordinary processes of respiration. Where the balance is once upset in this way in a body of water where things have become adjusted to a certain set of conditions, it is difficult to predict just what results will follow in the readjustment to new conditions; but it is safe to assert that practically all the living organisms in the water will be influenced to some extent. Even if the vegetation were not uprooted by the stirring up of the mud of the bottom, it is probable that its abundance would be greatly reduced by the constant roiliness of the water. This would in all likelihood affect the plankton or free-swimming organisms as well, and thus greatly reduce the natural food supply of the fish. In the large bodies of water these conditions are ameliorated to a large extent, since by the movement of the fish from place to place they are often absent from a given locality for considerable periods, thus giving the sediment an opportunity to settle and allowing the water to become clear; and even in smaller areas the fish are not feeding all the time. But it must be admitted that where there are a comparatively large number of carp in a pond the water is kept in an almost constant state of roiliness. In the case of running waters there is a further tendency to impoverishment in the carrying away of the rich mud while it is held in suspension in the water. There has been no direct evidence collected, so far as I am aware, to show to what extent this may be effective. It has even been claimed by some that dikes and dams are weakened in this way, by the destroying of the vegetation that held the mud in place, and the loosening of the mud itself.

The roiliness of the water caused by carp in supply reservoirs has, in a number of instances, proved to be a serious problem, and is one which has to be met with promptness. The only practicable remedy is the removal of the fish. In some places this can be done with comparative ease by persistent seining; but more often, especially in large reservoirs which present a diversity of conditions, this method is not feasible. In some cases it may even be necessary, where the disturbance is very great, to withdraw the water and drain the reservoir for the purpose of getting rid of the carp. An interest-

ing case of the way this problem was met in Lake Merced, one of the reservoirs for the water supply of San Francisco, is reported by Smith (1896, p. 395) in the paper that has already been quoted. A number of sea lions put into the lake apparently did the work very efficiently; but unfortunately this is not a method that it is always possible, or at least, practicable, to apply. Doctor Smith quotes Mr. Babcock, of the California Fish Commission, as follows:

> Carp have entered the Blue Lakes in Lake County. The Blue Lakes, three in number, were formerly very striking and beautiful bodies of water. A. V. La Mott now tells me that lower Blue Lake is so muddy that its beauty is gone, the carp keeping the water roiled all the time. Lake Merced, property of the Spring Valley Water Company, in the city and county of San Francisco, was so damaged by carp as to be almost useless to the company. The company employed four fishermen by the month to seine the lake, and during that time—some four months—bought 19 good-sized seals [i. e., sea lions] taken near Cliff House. These seals were placed in Lake Merced in 1891, and for a time the company employed men to go over the lake to pick up the pieces of dead carp that were so numerous as to be dangerous to the purity of the water. In the summer of 1895, at the request and expense of the water company, I engaged several Italian fishermen to go to the lake, and under our supervision they used all kinds of drag nets and seines in the lake and were unable to take any carp or any other fish than sticklebacks. The seals have grown very thin. Another effort was made in same manner with like results in the fall of 1895. I am of the opinion that there are no carp, big or little, in the lake at this time. The coming season the company will try again for carp, and if none is found the seals will be killed off and large-mouth black bass placed in the lake.

The planting and maintaining of large predaceous fish in waters where carp are objectionable will undoubtedly help to a large extent in keeping their numbers down, as they will prey upon the young carp. It is doubtful whether they will be of much effect in removing the larger fish, however.

Another point is mentioned in the above quotation which is often one of considerable importance, namely, the marring of the beauty of lakes and other bodies of clear water by carp, by keeping the water constantly muddy and roily. This is a problem which is apt to be encountered by park commissioners, and is to be met in the same way as in the case of the reservoirs. In parks, however, the usefulness of carp as a source of interest to visitors, who take pleasure in feeding them, may be considered as offsetting their undesirability in other respects, though gold-fish are usually preferred on account of their more showy appearance.

RELATION OF THE CARP TO OTHER FISH.

Perhaps more complaint has been made against the carp by anglers and commercial fishermen for its alleged destruction of other fish than by the sportsmen for its harmfulness to the feeding grounds of ducks. These complaints have come from nearly all quarters, and it will usually be found that they arise from a general sentiment rather

than from definite information. It is a noticeable fact that this sentiment is much less general, or may be largely replaced by one almost as unreasoning in favor of the carp's entire harmlessness, in regions where this fish is commercially valuable on a large scale. The charges may in a general way be divided into four headings: (1) That carp eat the spawn of other fish; (2) that carp eat the young of other fish; (3) that carp prevent the nesting of such fish as the basses; (4) that carp produce unfavorable conditions—chiefly roiliness of the water—that drive other fish away.

In the Great Lakes region the fishes that are generally conceded to be in most danger from the carp are the bass and other members of the same family (crappie, sun-fish, bluegill), and the white-fish. It is obvious that they can hardly affect directly such other commercial and game fishes as the wall-eyed pike and sauger (*Stizostedion*, commonly called "pickerel" on the Great Lakes), or perch[a] (*Perca flavescens*), or trout; nor do I know of specific complaints of damage to the herring (*Argyrosomus*), sturgeon, or the true pikes (Esocidæ, "pickerel" of the inland waters). Most of these do not lay their eggs where they are likely to be troubled by carp, and some are probably considered able to take care of themselves. Still it seems that carp might easily affect wall-eyed pike, in cases where the eggs are attached to water plants; and if they affect white-fish they probably also affect herring, whose eggs are laid at the same time and presumably in the same places.

The first of the complaints enumerated above, viz, that carp eat the spawn of other fish, is perhaps the one that has been most persistently maintained. One can scarcely read a communication by one of the opponents of the carp without finding in it a statement to that effect. Nevertheless, few, if any, direct observations are recorded. The argument is something like this: Other fish, such as the bass, are decreasing, while the number of carp is, or at any rate has been, steadily on the increase; carp will eat practically anything; therefore, the decrease of certain other fish must be due in large part to the fact that the carp devour their spawn. What I wish to point out is that while the two premises may be true, the conclusion is by no means a necessary one. It can not be deduced from the above premises without other facts, and those facts have not been supplied. They might be of two kinds—first, direct observation of the eating of the spawn of other fish by carp; and, second, by the finding of the spawn of other fish in the

[a] With regard to the perch, at the thirtieth annual meeting of the American Fisheries Society both Mr. Dickerson, of Detroit, and Doctor Parker, of Grand Rapids, Mich., expressed their opinion that the carp is indirectly harmful to the perch through the destruction of the vegetation. Doctor Parker remarks (Transactions of the Society, 1901, p. 124): "You must go back to the vegetable for the rehabilitation of waters. If you destroy vegetation and the larvæ, you destroy the minnows, and the perch have no minnows to feed on, unless they can eat the young of the carp, which they do not appear to do, but the black bass will eat the young of the carp and will thrive. Therefore you may look for an increase of the black bass, a decrease of the minnows, and also of those fish that feed upon the smaller minnows."

stomachs of carp. Although it is stated that carp do go about over the spawning grounds of other fish and that they devour the spawn, with the exception of the little given in this paper relative to the white-fish, I do not recall a single case that has been reported upon where sufficient evidence has been adduced to show that such is really the case. The absurdity, for example, of an assertion which has recently been made by a writer in Forest and Stream (Chambers, 1904) is obvious on the face of it. This partisan, after deprecating carp as a food fish and speaking of its habit of uprooting wild rice, adds:

> When the stomach of one caught upon the St. Clair Flats was opened last autumn, it was found to contain at least a double handful of rice, while as an illustration of their destructiveness upon the spawn of other fish it may be mentioned that *a gallon of spawn* which had been devoured was taken from an 18-pounder—a weight which the carp frequently attains.

The italics are mine. The enthusiasm of partisanship has apparently led this observer into mistaking the spawn of the carp still in the ovary for that of some other fish which has been devoured, for it seems altogether out of the question that the stomach of one 18-pound carp should hold a gallon of spawn. A double handful of rice—wild, or Indian, rice (*Zizania*), I suppose is meant—might well be present. The greatest amount of material which I have ever taken from the alimentary tract of a single carp would surely amount to much less than a pint, though I can not say that by distention it might not hold more.

In my own researches at the St. Clair Flats, where the black bass were nesting in numbers, I spent much time in attempting to get direct evidence relating to the question at issue. Most of these observations were made in a small bay where the general water level in the deeper parts was about 3 to 5 feet. The bottom was composed of a fine clay, in most places rather light in color. Practically the only vegetation in this portion of the bay consisted of scattered groups of bullrushes, each clump usually radiating in long lines from a common center. The bass[a] nests were in this open part of the bay, large circular excavations, a few inches deep, and usually appearing much darker than their surroundings on account of the removal of the top soil. As a rule they seemed to be placed near the lines of bulrushes, and were usually plainly distinguishable for a considerable distance on account of the clearness of the water.

Conditions about the margin of the bay were entirely different. Here the shallow water, 1 to 2 feet or so deep, was thickly grown up with vegetation—flags, sedges, lily-pads, etc.—and was succeeded by wet, marshy, grass-covered ground. The bottom here was largely

[a] I believe these were the small-mouthed black bass (*Micropterus dolomieu*), though I find no record of the species made at the time.

soft, and black on account of the decayed vegetable matter. In this shallower area all about the bay carp were often very numerous.

In the first place much time was spent in trying to learn whether the carp ever intruded in the central portion of the bay where the bass were nesting. It seemed very probable that they would cross the bass nesting-grounds, at least in going in and out of the bay. But I was never able to observe a single carp actually on these grounds, though I at one time frightened a number of them in near shore which started out in that direction. A fyke-net was set with a view to intercepting any carp that might cross the tract covered by the bass nests, but with negative results. These fish are so wary, however, that it is very doubtful whether they would have entered the net had they gone that way. At another place I at one time had a large minnow seine drawn over a portion of bottom where a few bass were breeding and where I had reason to suspect there were carp present. Besides the small fish captured the seine brought in a bass, a pike, and two carp, which seems to show that they may at times go in close proximity to the area covered by the breeding bass, if not actually upon it.

In the bay mentioned above I built a scaffold at the border line between the bass grounds and the shore zone, with the idea of having a more commanding view of portions of both. On this I spent many hours of vigilant watch, and although a bass which had a nest near by soon became accustomed to the structure and resumed his care of the eggs in the nest, and although carp sometimes appeared within my range of vision in the water on the shoreward side, I never saw one of them on the outer side, where the bass nests were located. Since I have frequently seen schools of these fish lying quietly in water which seemed to present the same conditions, except that the bass were absent, I feel justified to some extent in concluding that as a general thing carp avoid the actual breeding areas of the bass.

The question has often been raised, and has been much discussed, as to whether a black bass would drive a carp away from its nest. A number of opinions were expressed on the subject at the thirtieth annual meeting of the American Fisheries Society, held at Milwaukee in 1901 (see the Transactions of that meeting, published in the same year, pp. 114–132). It appeared to be the consensus of opinion of the gentlemen assembled there that the bass is fully able to take care of itself, while it was further claimed by some that the bass were actually increasing owing to the extra supply of food furnished by the young carp. Below are given some extracts from the discussion referred to:

Mr. TITCOMB. Is it not a base slander upon the bass to intimate that it would allow a carp to touch its spawn?

Doctor BARTLETT. I should think so.

Mr. BOWER. I think that where bass and carp inhabit the same water it is natural that the bass should increase. We have been hatching black bass for a number of seasons in ponds where we have had an opportunity to observe their spawning

operations from the time the male fish begins to prepare the bed until a good many days after the hatching is completed, and we know that the male bass guards the bed against all intruders. He will put up the stiffest kind of a fight against any animal that approaches the bed with a view of preying upon the spawn. There is no danger of a carp ever looting the spawn from a black bass bed. On the other hand I do not think the carp can retaliate against the bass in any way, shape or form. While the bass is preying on the carp, the carp can not come back at them in any way. In other words, in the interchange of hostilities between the two species, the bass gets the better of it at every stage of the proceedings, and I think it is a perfectly natural result that the bass should increase in waters where there is an abundance of carp.

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Mr. LYDELL. I never have known but a single instance where the carp has destroyed the spawn of the black bass, and I never knew of their destroying any other spawn. I have handled and opened what few carp were caught at the Detroit river, Belle Isle, fisheries, during the last ten years, but never found any spawn in them.[a]

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The PRESIDENT [Mr. DICKERSON]. I have made this assertion, that no carp ever got hold of an egg of a black bass unless Mr. Bass had first been taken off from that spawning bed. I do not believe there is such a thing as a carp ever having devoured a single egg from a black bass bed where the black bass was on the bed. Of course if the beds are deserted that is different, but as long as the bass is alive and guarding the bed, no carp ever got a single egg.

Other opinions were expressed, all with the same tenor; but it must be remembered that these are in most cases only opinions. They are expressed by practical fishermen, however, men who have had more experience with the black bass and with the carp than almost any one else in this country, and for this reason their opinions must be given weight.[b]

In the Transactions of the Thirty-second Annual Meeting of the same society (1903, p. 54) a statement similar to the above is made by Mr. J. L. Leary. It is in part as follows:

As to his [the carp's] destroying the eggs or young fish, it is not a fact. My experience is that I could not raise the crappy in clear water, and I adopted the plan of putting so many carp in crappy ponds, and I raised some crappy and no carp, showing that the young carp are all destroyed by the crappy. The smallest sunfish can chase him away, for the carp is a big coward; the carp is a rapid grower and a good fish.

While we are discussing the case of the carp it may be well to give a little more fully the ideas of two members of the American Fisheries Society (Transactions of the Thirtieth Annual Meeting, 1901) as to the probable increase of these fish, as has been suggested above, on account of having young carp for food. Mr. Dickerson, of Detroit,

[a] This fishery is not prosecuted during the spawning season of the bass; the statement is meant to refer to white-fish spawn.

[b] This question should be tested by introducing a few carp into a bass breeding pond.

speaks of the complaints of the fishermen that carp are destroying the bass fishing on the St. Clair Flats, and then adds (p. 118):

> But notwithstanding their claims the bass fishing on St. Clair Flats has been better during the last three years than at any time during fifteen years previous, and we have not planted any bass either. I can not account for it in any other way except that the environments of the carp and black bass are absolutely different. Black bass likes a clean, pure, sandy bottom, and the carp lives on a muddy, weedy bottom. I believe that the carp is a good thing in many waters where black bass thrive. I believe that the bass fishing at the flats has increased by reason of the food that young carp make for the bass, though he was not planted there.

Dr. S. P. Bartlett, of Illinois, who has always been a strong partisan for the carp, says (Transactions American Fisheries Society, 1901, p. 120):

> When we take into consideration the fact that is so well known of the voracious habits of the black bass, it shows an all-wise provision of nature to supply a very large quantity of coarse fish to feed the other fishes, and I believe as firmly as I am standing here that if the carp had not been introduced in the state of Illinois, the buffalo having become almost extinct in our waters although it was once the great commercial fish that the bass would have been gradually taken out entirely from the list. As it is now, I want to repeat the statement that we have more black bass than ever, and our carp certainly have increased in a greater ratio than ever before.

This statement, so contrary to what is so often maintained of the bass at the Flats, seems the more plausible when we read in the Report of the Michigan Fish Commission for 1885 (p. 11) the statement that the decline of black bass in Lake St. Clair and the Detroit River was mentioned in the early eighties, and was said to be due partly to their being taken in nets, contrary to law, and partly because they were not protected. At this time they certainly could not have been influenced by carp.

Still more evidence along the same line is brought forward by Townsend (1901). After giving figures showing the increase in the catch of carp in the Great Lakes region and the Ohio and Illinois basin, he continues (p. 178):

> These figures show an increase in the quantity of carp derived from the above-named waters amounting to nearly nine times the quantity yielded six years ago. During the same period the total fishery products of Lake Erie increased more than 15,000,000 pounds and those of the Illinois River more than 5,000,000 pounds. There are, therefore, no indications that the presence of the carp has produced any injurious effect on the native species associated with it, but, on the contrary, its presence may have a salutary effect, the young of the carp doubtless being food for black bass and other species. It is certain that the black bass has increased in the Illinois River along with the carp, the yield of black bass in 1899 being greater than ever before, amounting to over 70,000 pounds.

Regarding the relation of carp to some of the other fish I have only a few observations of interest. It seems a noteworthy fact, however, that I have found the dog-fish (*Amia calva*) on its nest, and apparently unmolested, right in the midst of a portion of the marsh which

was traversed daily by the carp in their search for food. Moreover, in the shore zone of the bay where the black bass were studied I found nests of an unidentified species of sun-fish or bluegill, and this was in the regular beat of the carp. The owners of these nests always left them upon my approach before I could get a good view of them, and immediately after their departure a number of small fish which had been swimming about in the neighborhood pounced in and began devouring the eggs. I succeeded in securing a few of these while they were committing their depredations. Those I captured were a small perch (*Perca flavescens*), a related form sometimes known as log-perch or hog-perch (*Percina caprodes*), and a small minnow (*Notropis whipplei* [a]). All had their mouths and gullets crammed with eggs from the temporarily deserted nest. Here we have a suggestion as to one of the important factors that may tend to reduce the number of bass. At the St. Clair Flats, owing to the cold water brought down from Lake Huron, the bass usually spawn considerably later than they do in the interior waters of the state, which become warm more quickly. This is so late, in fact, that the close season prescribed by the law does not protect them at the time they are spawning, and as a consequence great numbers of them are taken by the bass fishermen directly off their nests. In addition, many are also speared, contrary to law, by certain lawless residents of the region. The poacher approaches as close as possible in a duck boat to the bass as it guards its nest, and when within long range throws his long-handled grain. Undoubtedly more bass are hit in this way than are actually secured, for I have seen numbers of them dead along the shore which showed the marks of the spear upon them. What the consequence is as soon as the parent fish is removed it is easy to see. Good food does not lie around unprotected long when there are hungry fish in the vicinity, and it is very probable that if a carp happened along at this time he would not hesitate to avail himself of the opportunity, for a familiar proverb might well be perverted to apply—all is food that comes to the carp's mouth.

In summing up with regard to the damage done by the carp to the spawn of other fish, especially the black bass, we find that there is little in the nature of direct observation, but what there is seems to point to the conclusion that there is little danger to the eggs of these other species so long as they are being guarded by the parent fish. That the carp does eat spawn when occasion presents is not denied even by Doctor Bartlett, the carp's greatest friend. He says, in the Transactions of the Thirtieth Annual Meeting of the American Fisheries Society, 1901 (p. 120):

In order that I might know positively what amount of injury had been done by the introduction of the carp into the waters of the Illinois, I took occasion when

[a] This minnow was kindly identified by Mr. T. L. Hankinson.

carp were first brought upon the market and the hue and cry raised as to their destructive qualities, to open and to be present while hundreds of carps were opened, to see if I could find in their stomachs anything that would indicate that they took the fry of other fish or spawn of other fish. I can not say that I have never found the spawn of other fish in their stomachs, but when I have found such spawn it has been of such a nature as led me to believe that it was such spawn as floated on the surface of the water, and that the carp took them in, in that sucking motion that he has, going around on the surface of the water.

From data given by Doctor Smith (1902) it appears that the blame for the destruction of shad eggs has been wrongfully placed upon the carp. He says that observations in the Potomac River show that the carp do not molest the shad eggs, as they do not go upon the spawning grounds. The greatest amount of shad spawn is consumed by cat-fish and eels. This was shown by having a large shad seine hauled over grounds where the shad apparently had just spawned. Many shad and alewives were caught, but mostly cat-fish (about 5,000 *Ameiurus albidus*) 6 to 18 inches long, and every one of these, so far as observed, was gorged with shad eggs.

With regard to the charge that carp devour the young of other fish, any damage that it may do in this way is certainly so slight that it need hardly be considered. It can not be said that carp never do capture smaller fish, for two or three cases have been reported—one where a carp ate some three minnows that were confined with it in a small aquarium (Gurney, 1860)[a], while in the other cases fish were said to have been found in the stomach. The carp is obviously unadapted by structure for capturing other fish for food. Its mouth is comparatively small and adapted to "sucking," while, furthermore, there are no teeth which could be used in holding living prey. Its only teeth are several rounded, knob-like structures situated well back in the "throat," and known as pharyngeal teeth, and are of service only for crushing and grinding.

As to the third and fourth points, that carp prevent other fish from nesting and that they produce unfavorable conditions which drive other fish away, I know of no proof on either side further than what has been brought out in the foregoing discussion.

I have chosen to consider separately the relation of carp to the white-fish, because the conditions in this instance are rather different and distinct from those in the case of any of the other fishes considered. Then, too, the white-fish fishery is one of the most important in the Great Lakes, and if it were found that the carp interfered seriously with the spawning of the white-fish it would be a very strong point indeed against him.

The white-fish of Lake Erie make an annual migration from the

[a] "A specimen of the common carp, between 5 and 6 inches in length, was lately observed to devour three small minnows, each of about an inch and a half in length, which were confined in the same aquarium with him. One of these the carp seized immediately the minnow was placed in the aquarium and swallowed it whole, head foremost." (Gurney, loc. cit.)

deeper eastern portion of the lake to the shallow reefs at the western end, especially around the islands there, in order to deposit their spawn. The time of this migration varies somewhat with the temperature, but at an average the spawning usually begins in early November and is at its height during the middle or latter half of that month. The eggs are scattered loosely over the rocky bottom.

During my visit to North Bass Island in the summer of 1901, I heard much complaint by the local fishermen, who maintained that in the fall carp did great damage on the spawning grounds of the white-fish. Their statements may be summarized as follows: Carp are abundant about the Bass Islands when the white-fish are spawning; carp eat the spawn of other fish, especially white-fish; white-fish spawn has been taken from a carp's stomach; when carp are numerous on a reef, the white-fish are not there, being driven away by the carp. Carp are not caught here for commercial purposes to any great extent, and the prejudice against them was very strong. At such places as Port Clinton on the mainland, on the other hand, where carp are shipped in enormous quantities, and which is also one of the principal ports for the white-fish fishermen, I found the belief that carp were detrimental to the white-fish either entirely absent, or at any rate not nearly so strong.

In November, 1901, I proceeded to Lake Erie in order to make what investigations I could in the matter. At the time of my arrival, shortly before the middle of the month, white-fish were beginning to be caught in considerable numbers, though very few of the fish were ripe. A week or so later the numbers caught increased greatly, and the spawning seemed to be at its height. The season was an unusually stormy one, with strong northwest winds nearly every day, and one northeaster of several days' duration. The temperature was low during nearly the whole time and there were frequent snow flurries. The fishermen said that probably, owing to the rough weather, the fish did not go upon the reefs to spawn in such large numbers as was usually the case, so that the gill nets, set on the reefs, got comparatively few fish, while many more were caught in the pound nets in deeper water. I spent several days both at Port Clinton and at the islands; at the former place both pound-net and gill-net fish were brought in; the fish landed at the islands were all taken in gill nets.

Very few carp were brought in at either place, and none of them was large, averaging probably less than two pounds. On one day when I visited the pound nets with the fishermen, only two carp were taken. The stomachs of most of those examined at Port Clinton were empty, or nearly so, and in only two cases was any white-fish spawn found. At the time the preliminary statement of this work was published in 1903 (Report of the United States Commissioner of Fish and Fisheries, for 1902, p. 130) only a general and rather superficial exam-

ination of these stomachs had been made, and it was stated that no white-fish spawn had been found. When a more careful examination was made later, one white-fish egg was found among the contents of each of two stomachs. (See Nos. 23 and 24, p. 572.) The rest of the material was mostly remains of insect larvæ, entomostraca, shell fragments, and algæ.

November 27 was spent at North Bass Island and several dozen carp were examined. These fish, all small ones, 30 to 40 cm. (12 to 16 inches) long, were brought in directly from the gill nets, set in from 10 to 25 feet of water, and for the most part on the reefs. Most of the fish had some food in the alimentary canal, and in some cases the stomach was well filled, showing that they had been feeding very recently. Reference to stomachs No. 29 to No. 32 will show that the food was of the same general character as had been found at Port Clinton. Here, again, one stomach contained a single white-fish egg (No. 31).

The facts obtained lead me to quite a different conclusion from the assumptions made by the fishermen. That carp do occur on the spawning grounds of the white-fish is true, and, furthermore, they seem to be moving about and feeding in spite of the lateness of the season and the low temperature of the water. These are mostly small fish, however, and the number of them on the reefs appears to be comparatively small as well. The eggs of the white-fish, not being adhesive to any great degree, probably become widely scattered, and unless the carp were present in large numbers the relative number of eggs destroyed would be small; and that such is the case seems to be proved by the examinations of stomach contents made. That carp capture the young white-fish is even more to be doubted, and certainly no instance has been reported where such is known to have been the case. My conclusion is, then, that while the carp may eat some white-fish spawn, the amount so consumed is so small as to be practically insignificant, especially in comparison with the host of other forms which probably prey upon the eggs now as they have always done in the past. I suspect that by no means the least enemy to these eggs is the common mud puppy (*Necturus maculosus*—called "lizard" by the fishermen) which is often taken in numbers in the pound nets. And, furthermore, the danger to the white-fish spawn has been largely overcome in recent years by the operations of the Bureau of Fisheries, in hatching the eggs in jars and turning loose the young fish in the spring. It has generally been conceded to be due to this, and certainly in spite of the increase of carp, that the white-fish have been on the increase in Lake Erie in the last few years. The catch in 1901 was an especially good one, and was said by the fishermen to exceed any for many years previous.

FOOD VALUE AND USES OF THE CARP.

At the time of the introduction of the carp to this country a greatly exaggerated idea became prevalent as to its value as a food fish, or, at least, as to its qualities as a food fish. This will be noted by a glance at the statements which were sent to the Bureau of Fisheries by those who had received the fish, and which were compiled and published by Smiley (1884, 1886, 1886*a*, etc.) a few years after the fish first began to be distributed. Some of these enthusiasts even went so far as to say that the flesh of carp was of a better quality than that of the trout, white-fish, salmon, and many other of our finer fishes. How such a notion should have become so generally distributed it is difficult to see, for at no time were such claims made for the carp by those who were most interested in its introduction, although it is true that probably most Americans will hardly agree with Mr. Hessel (1881, p. 897) when he asserts that it "is one of the most excellent fresh-water fishes." Mr. Hessel, however, was a German, and in Germany the flesh of the carp is much esteemed. What early habitude may do in determining likes and dislikes as regards food is illustrated by the fact that Germans who live near the Great Lakes, where they could easily get what we should consider better fish, often eat carp from preference, while the American fishermen rarely, if ever, use the carp themselves. As will be mentioned later, the reason for this is perhaps a matter of cooking.

At the present time the popular prejudice is in most parts of the country generally against the carp as a food fish. It is even stated by many that it is utterly worthless. A common complaint made against it is its muddy flavor, and that this often exists is admitted even by those who like the fish best. This flavor has, in fact, always been recognized by carp culturists in Europe, and special precautions are taken to avoid it. It is said to be present in those fish which have lived in very muddy places, especially where the water is stagnant and the temperature rather high. If the carp are removed from such places and kept for a short time in fresh running water, the muddy flavor is claimed to be removed entirely.[a]

In the chapter dealing with the carp in Europe, it has been shown how extensively this fish is used for food there, especially in Germany and France. It is the custom in many places there to keep the fish alive in tanks at the market, thus selling them to the customers not only in a fresh but actually in a living condition.

Many methods have been given for cooking carp—undoubtedly any

[a] Day (1880–1884, p. 162) says: "To improve their flavour Mr. Tull (Phil. Trans. Roy. Soc., 1754, p. 870) castrated these fish and found that subsequently they grew more rapidly, fattened more readily, and were of a superior flavour." Similar experiments have frequently been mentioned, especially in the older works, but there seems to be no record of the attempt having been made recently. In this connection see Weddige (1882).

German knows what are best; but I do not feel competent to judge of them. In general, it would seem that the flesh is best boiled and baked and prepared with some sort of dressing. Dr. S. P. Bartlett (1903, p. 49) gives the following suggestions:[a]

I feel sure that most of the prejudice to the carp as a table fish is from the fact that they are too often taken from the warm water, fried and broiled without preparation. Their rapid growth and the warm water they are taken from, has a tendency to make them soft. I have found the best mode of preparing them as follows: Kill as soon as caught, by bleeding, taking out all of the blood. Skin, soak in salt water for several hours, then parboil and bake, basting frequently. They are frequently served here as a boiled fish, covered with proper dressing. It takes but a slight stretch of the imagination to place [them] on bill of fare as anything from bluefish to buffalo. To-day I had bluefish served with my soup at one of the principal hotels and it would have passed as such with the average man, tell-tale bones, however, said carp.

Carp is probably more often served under the name of some other fish than is generally suspected. Mr. John W. Titcomb gives an instance where it was served at his instigation which shows that this fish when well prepared compares so favorably to many others that few suspect the difference. At the dinner in question there were 224 people present. Mr. Titcomb's account of it is here given (Titcomb, 1902, p. 36):

That the carp is unfit for food, as claimed by many sportsmen, may be contradicted by the statement that at the dinner of the Vermont Fish and Game League held at Burlington, Vt., in January, 1902, at which were entertained the members of the North American Fish and Game Protective Association and representatives of the fishery departments of three Provinces in Canada, the carp was served under the title of "baked red snapper," and was a very palatable dish. The deception was not planned by the hotel managers, but at the request of the president of the league in order that the carp might be fairly tested as to its edible qualities. While a great many of those who ate the fish knew that it was not the genuine red snapper, it is probable that not one of the guests had any idea that he was eating the despised carp.

It is probable that many hotels and restaurants would find it profitable to have carp regularly on their bills of fare, especially such as have considerable German patronage. The report of the Commissioners of Inland Fisheries and Game (of Massachusetts) for 1893 (published in 1894) quotes the statement that at that time at least one restaurant in Cleveland regularly had carp on its bill of fare; and a

[a] Doctor Bartlett also gives a recipe for "carp omelet" or "carp jelly," said to be of Swedish origin. It was given to him by Doctor Weiss, of Ottawa, Ill., who declares that the perfected product is equal to the imported fish jelly that brings $1 per pound. The recipe is as follows:

Take a 6 or 8 pound carp; scale and skin. Leave head and skin [fins?]. Cut into small pieces and place in boiling water just sufficient to cover, and add salt, coarsely ground pepper, allspice, and a bay leaf or two. Boil about twenty minutes or until perfectly soft. Remove from the fire, remove pieces of fish from the water, but preserve the water. Break the pieces so as to be able to remove all of the bones thoroughly. Skin fins and head pieces. Strain liquid through a colander and if necessary add a cupful of gelatin, previously dissolved, to this liquid. At the same time add such other pieces as may be desired. Add the original pieces of fish to the liquid or gelatinized liquid. Stir and place on ice until solidified.

recently published menu[a] of the café luncheon of the Waldorf-Astoria, New York, for April 16, 1902, contains the item, "Carp, Rhine Wine sauce" at 65 and 40 cents.

It is not maintained, however, that the attempt should be made to put carp on an equal footing with our admittedly finer fishes. It is merely desired to show that if the prejudice at present prevailing against it as a food fish could be removed it would be much more extensively used than at present. Even now hundreds of tons of carp are being consumed yearly in the larger cities of this country, though the demand can still not be considered equal to the possible supply. The amount of these fish now used will be considered under the subject of the carp fisheries (p. 617). The sale is at present mostly limited to the poorer classes in the cities, and especially to the Jewish people. For this trade it is necessary that the fish be shipped "in the round," and those that have previously been cleaned will not be accepted.

Several methods of specially preparing carp have been tried to some extent in this country, but none of them has as yet been attempted on a large scale. I was told that canning carp had been tried in Cleveland, but was unable to get any definite information on the subject. If the dogfish of our coasts, a species of shark, can be put up successfully in this form, as is now maintained, it seems that as much might be expected of the carp. The greatest difficulty would be, in both cases, in overcoming popular prejudice and in establishing a market for the product.

A few firms along Lake Erie have been smoking a considerable quantity of carp, which has, however, never had a wide market, but has been disposed of locally. For this purpose the larger fish are used, weighing usually 12 to 15 pounds. With a sharp knife the skin and scales are cut off in broad strips (about three to a side), the cuts not going so deep, however, but that the imprints of the scales still show on the flesh. The head, viscera, and fins are all cut away, and the fish is then cut up into transverse sections or "steaks" some 2 or 3 inches in thickness. This last process is readily accomplished by means of a sharp knife fixed in a long-handled lever, as is shown in figure 4, plate II (the operator to the left). Two skilled operators can prepare a large number of fish in this manner in a comparatively short time. The steaks are strung on long iron rods and are smoked in the ordinary way. I was told that this product was sold as smoked carp and retailed at about 15 cents per pound. The claim was made that "except for the bones it could not be told from smoked sturgeon," and that I myself tried I found to be very palatable. At a retail market in Sandusky I actually found smoked carp on sale at 18 cents per pound under the name of smoked sturgeon. The larger fish are not readily

[a] This menu has been reproduced in Transactions American Fisheries Society, Thirty-second Annual Meeting, 1903, p. 123, and in the Report of the [Illinois] State Board of Fish Commissioners, 1900-1902.

sold in the round, those of 3 to 5 pounds' weight being considered best for cooking, and it seems that smoking should be an important way to utilize the less desirable size. I am unable to give even approximate figures of the amount or value of this particular product at this time, but it seems to be an industry which is capable of being developed upon a paying basis to a much greater extent than at present.

Wholesale dealers who have tried the experiment of salting carp down, as is done with the herring, and thus holding them over to a season when they would demand a higher price, inform me that the experiment was not a success. This is probably due largely to the fact that the Jewish people are by far the largest consumers of carp in this country, and they want the fish as fresh as possible. It was also the opinion that the salting had a deteriorating effect upon the quality of the flesh. It is a common practice in most of the large fish houses, however, to freeze large quantities of carp when the supply is greatly in excess of the demand at the time and to hold them over in this condition until there is a market for them.

The scarcity of sturgeon and the high price brought by caviar naturally suggested to many the possibility of using the roe of the carp for their purpose. While the eggs are small, a single large female often contains a large quantity of them (see p. 574), and during the breeding season carp roe could be obtained in abundance. But those on the Great Lakes who have attempted to manufacture caviar from the roe of the carp have all reported a failure, complaining that in the process the eggs turn pink or red. Inquiries have been made as to whether this could be avoided. This change of color is probably always characteristic of caviar made from carp eggs, as is evidenced by the following quotation from Walton (1901 ed., p. 116):

> But it is not to be doubted but that in Italy they make great profit of the spawn of Carps, by selling it to the Jews, who make it into red caviare, the Jews not being by their law admitted to eat of caviare made of the Sturgeon, that being a fish that wants scales, and, as may appear in Leviticus xi, by them reputed to be unclean.

It is possible that similar caviar made in this country would find a ready sale in the large cities, such as New York and Boston, where there are large settlements of Jews.

It is said that in some parts of Europe "the palate, commonly termed the 'tongue,' is considered a great delicacy."

In common with numerous other fishes certain parts of the carp were formerly considered to be of great medicinal value. Thus Walton, on the page quoted above, says that "physicians make the galls and stones in the heads of Carps to be very medicinable."

Besides being of value as an article of food there are a number of other ways in which carp may prove to be most useful. Perhaps the most important of these is in helping to keep in check the increase of noxious insects which pass their larval stages in the water, and especially

that ever-present cosmopolitan pest, the mosquito. Howard (1901, p. 161) emphasizes the importance of fish in this respect and gives an instance where carp are said to have been very effective, though he himself doubts whether carp could have been the fish that destroyed the larvæ. He says:

It was stated a number of years ago in *Insect Life*, that mosquitoes were at one time very abundant on the Riviera in South Europe, and that one of the English residents found that they bred abundantly in the water tanks, and introduced carp into the tanks for the purpose of destroying the larvæ. It is said that this was done with success, but the well-known food-habits of the carp seem to indicate that there is something wrong with the story. If top-minnows or sticklebacks had been introduced, however, the story would have been perfectly credible, and it points to the practical use of fish under many conditions. Some years ago Mr. C. H. Russell of Bridgeport, Conn., described a case in which a very high tide broke away a dike and flooded the salt meadows of Stratford, a small town on the north side of Long Island Sound. The receding tide left two small lakes nearly side by side and of the same size. In one lake the tide left a dozen or so small fish, while the other was fishless. An examination by Mr. Russell in the summer of 1891, showed that while the fishless lake contained tens of thousands of mosquito larvæ, that containing the fish had no larvæ.[a]

From the results of the stomach examinations recorded in the earlier pages of this report it does not seem that Howard's conclusion that carp did not destroy the larvæ in the tanks in question is warranted. While it is true that no mosquito larvæ were found among the intestine contents examined in connection with the present investigation, this may have been due to their small size; the fact that in some cases the food of the fish seems to have consisted almost entirely of insect larvæ makes it probable that those of the mosquito would be taken as well. Since it is reasonable to suppose that there was little or no other food in the tanks mentioned in the above quotation, it is all the more probable that the carp would there have eaten the mosquito larvæ, and I see no reason to doubt the original statement. It may well be that among our native fish there are some species, such as the stickleback and top minnow, which are better adapted to this purpose than the carp, but the latter is not for this reason a negligible factor. Undoubtedly many ponds that annually breed millions of mosquitoes need only to have plenty of fish introduced in order to abate the nuisance. If carp will do this as well as other fishes, it will serve a double purpose, as it can also be used for food.

Another, and perhaps even greater, benefit to be derived from the presence of carp has recently been suggested in a bulletin by Doctor

[a] In February and March, 1904, I had similar opportunity to observe the efficacy of fish in keeping the waters where they are present free from mosquito larvæ. About the hacienda at Chichen-Itza, Yucatan, there are a number of large tanks which are kept constantly filled with water for the stock and for other purposes. In some of these tanks mosquito larvæ were very abundant; but in the others, into which a few small native fish, locally known as "mojarras" (*Heros urophthalmus*), had been introduced, none were to be found. The same was true of two natural pools in the vicinity where these fish lived, while, on the other hand, large numbers of larvæ could be found in small hollows in the rock and other places where the rain water had been standing for a few days.

Stiles (1902), of the United States Bureau of Animal Industry. It was learned by Doctor Hutchinson, an inspector of the Bureau in Oregon, that sheep from the lowlands along the Columbia and Willamette rivers, where carp are numerous, are much freer of the fluke disease than those from other sections of the country, and it is suggested that the parasites (*Fasciola hepatica*) which produce the disease may be destroyed by the carp while in a cystic state (cercariæ) and attached to the leaves of grass or while they are in their intermediate host, the common fresh-water snail *Limnæa*. In a letter to the Bureau, dated December 2, 1901, Doctor Hutchinson writes:

> Prof. C. V. Piper, of the Washington Agricultural College, in conversation with me, mentioned the theory which I find is, as he said, extant in the minds of many farmers along this river, namely, that "leeches" [liver flukes], which were formerly numerous in the livers of cattle and sheep, have to a considerable extent disappeared since the introduction of carp into the waters of this river.
>
> While, of course, the farmers' idea is that the carp now consume the leech which, according to their view, the cattle formerly swallowed with the water while drinking, it is possible that there may be a practical connection between certain peculiar habits of this fish and the noticeable freedom from fascioliasis among the cattle and sheep ranged on the bottoms adjoining streams in which these fish are found, compared with animals coming from other sections where carp are unknown. About 75 per cent of the cattle and sheep coming from the western slope of the Cascades, exclusive of this Columbia River bottom, are infested with *Fasciola hepatica;* but from this particular portion only about 5 per cent are so infested.

And in another letter of later date (January 4, 1902) he adds:

> I am able to say that fascioliasis is much less common in animals from the lower Columbia and Willamette slough lands than from any other swampy districts of Oregon or Washington.

The carp have the more chance to destroy these parasites since the bottom lands are subject to annual overflow, and at such times the fish spread over the meadows and root out and eat much of the grass. Although I do not know that any species of *Limnæa* has been actually identified in the alimentary tracts of carp, there can be no doubt, as Doctor Evermann states in a letter quoted in the above bulletin, that carp do eat them when they are at hand. Doctor Stiles appears to have justification for his final statement that "the action of the carp in this case appears to be very strongly supported by the facts stated, and it seems that the introduction of carp into fluke districts generally would result in a great decrease of liver-fluke disease."

The Bureau of Fisheries, as well as some of the state hatcheries, have found that young carp make very good food for black bass, and according to the reports of the Bureau at least 1,000,000 of these small fish must have been used in this way in the years from 1894 to 1896. They have also been used to put into trout ponds to clean out the foreign matter, to destroy the algæ, etc. (Report United States Fish Commission for 1900 (1901), p. 57). It is possible that small carp would

make excellent bait for bass, and perhaps other fish, but I do not know that they have been tried.

On account of its hardiness and the readiness with which it will accommodate itself to small quarters the carp makes an excellent aquarium fish for exhibition purposes. At the large market in Boston there are several large carp in a glass tank so small that the fish now have barely room to turn around. It is said that these same fish have been there for a number of years.

When carp began to be common in Lake Erie it was suggested by many that perhaps the air bladders, or "sounds," as they are called, might be used for the manufacture of isinglass, which is extensively used in clarifying wines and in similar ways. At present about the only fresh-water fish whose sound is used for this purpose is the sturgeon, and the sturgeon fishery is comparatively so small that the sale of the sounds amounts to very little commercially. Those who had tried to use carp sounds for this purpose had not been successful. Nevertheless, at my suggestion, Mr. John Tufts, of the Cape Ann Isinglass Company, made further tests on some sounds which were procured for me by Mr. Cleaver, of the firm of R. Bell & Co., Port Clinton, Ohio. Mr. Tufts writes me as follows:

> In regard to the carp sounds which you sent me, will say that I have tested them and find that [they] will not answer our purpose, inasmuch as they do not seem to contain any glue.

Finally, where carp are taken in greater numbers than can be used for food, or where the attempt is being made to rid waters of them, they can always be used for the manufacture of valuable fertilizer. The importance of fish for this purpose and the extent of the industry in some parts of the country, have recently been well described by Stevenson (1903). Fish refuse is regularly sent from many fish houses in the region to the fertilizer factory at Sandusky, but under present conditions carp contribute very little to this, being shipped almost entirely in the round.

The possible value of the carp as a game fish will be discussed in a later section (p. 619).[a]

THE CARP FISHERIES.

Within the past decade the carp fishery has increased to such an extent in the general regions of Lake Erie and the Illinois River that it now forms a recognized and independent industry. Although it

[a] There is one purpose for which the carp would afford valuable opportunity which has not been mentioned—that is, as material for scientific study of variation and heredity among fishes. Experiments in this line have been actively prosecuted in recent years, especially with plants and mammals; but so far as I am aware nothing has been done as yet with a fish. That the carp would be an excellent subject for such experiments is evident from its great variability, its adaptation to domestication and the consequent ease with which it can be reared, its hardiness and rapid growth; and, finally, its great fertility, affording abundant material for quantitative results. Probably the only rival of the carp as a fish for this purpose would be the gold-fish, which might be preferable on account of its smaller size.

is carried on to some extent throughout the entire year, and some persons devote their whole time to it, the bulk of the fishing, in the Lake Erie region, comes in spring and summer, when the number of men engaged is greatly augmented. Many of these persons are professional fishermen who at other seasons are engaged in catching other kinds of fish; but many also are farmers, usually living in the vicinity of the fishing grounds, who supplement the income of their farms in this way. For this reason it is very difficult to estimate the number of men engaged in carp fishing, either for a part or for the whole of their time.

By far the greater number of carp marketed are taken in seines, and the methods differ only in details from those employed in seining generally. For this reason I shall give but a short description of the methods employed, and shall confine my remarks to the fisheries along Lake Erie and the adjacent waters. Apparently about the same methods are employed by the Illinois fishermen. (See illustrations in Illinois fish commissioner's report, 1900–1902.)

Some of the fishermen, especially those who fish along the shores of Lake Erie, make their headquarters in the cities where the wholesale houses are situated, making trips of two or three days, or even a week or more duration along the shores, and running back when they have a load of fish. These trips are made usually in open, flat-bottomed boats, of the style known on the lakes as "seine boats" and "pound boats." They are rigged as single or double "cats," but with the sail extending beyond the gaff to form a sort of permanent topsail. Others, and especially the farmers who fish for only a portion of the year, usually have a permanent camp established near some of the marshes. The fish when caught at these places are transferred at once to live-cars if to be kept but a short time, or to artificial ponds if they are to be kept longer, and are later sent to the wholesale houses either in wagons or by boat.

SEINING.

The seines used in this fishing are commonly 40 to 50 rods in length, about 18 feet deep in the middle and 10 feet deep at the ends. The middle portion or bag is generally about 5 rods long and has a 3-inch mesh, while the wings have a 4-inch mesh. Longer seines—to a length of 80 rods—are sometimes used, but are usually found to be too inconvenient. The cork-line is well supplied with floats to keep it up, but there are usually no weights on the lead-line. The lead-line is made shorter than the cork-line, however, so that it hauls somewhat ahead of the latter and hugs the bottom. The seine boats commonly used are open, flat-bottomed, centerboard boats about 20 to 30 feet long, square at the stern, and fitted with a single mast (fig. 3, pl. II). The seine is loaded into the stern of the boat in such a way that it can be paid off easily, and is taken to a ground where the fishermen have

reason to think there are carp. There are usually certain definite beaches where the hauls are made, places that are known to be comparatively free of vegetation and snags. As the summer advances it becomes more necessary to make the hauls on regular grounds, which are thus kept comparatively free of weeds. Where the seine has not been more or less regularly hauled the weeds become so abundant that it is impossible to make a good seine haul over them, for the lead-line trips and can not be made to hug the bottom. The various hauling grounds are patrolled with considerable regularity, and as soon as the fish come on in any numbers the fishermen are usually aware of it.

For a seine of the size mentioned a crew usually consists of not less than four men, though two crews sometimes help each other haul, thus reducing the labor. Nominally the waters are free for any one to fish in them, but as a matter of fact certain crews come to have a feeling of ownership for the hauling grounds they have established, and in this way they assume rights which are generally respected among themselves by an unwritten law.

Arrived at the hauling grounds, the fishermen proceed with caution, making as little noise as possible, so as not to frighten the fish. A long brail rope is bent to each end of the seine. The free end of one of these is left on shore, where a part of the crew remain as well, and the others row the seine boat out in a big sweep around the hauling ground. First the brail rope is paid out and then the seine itself, and finally the other brail rope is carried to the shore at a considerable distance from the point of starting. One person in a small duck boat usually follows along the seine to see that it sets right, and that it has not caught on any snags. The brail ropes are now passed around the drums of wooden reels or windlasses, and wound slowly in, one man keeping the line taut while one or two others wind in. In the meantime the fisherman in the duck boat follows along the net as it is gradually brought in, watching to see that it does not trip and freeing it if it catches.

When the brails have been brought close into the shallow water the two ends of the seine are carried along shore to some median point, and the net is now pulled in directly, hand over hand. In order to keep the lead-line down to the bottom a "jack" or "roller" is pushed down into the mud, so that the line runs under a sort of wooden spool. In this way the seine is gradually hauled in until all the fish are bunched in a small portion of the bag (figs. 1 and 2, pl. II), from which, with short-handled dip nets, they are either transferred directly to floating wooden crates or live-cars, or are placed in a boat and later transferred to the cars (fig. 3, pl. II.) The seine is then again loaded upon the seine boat, and if another haul is not to be made soon is taken ashore and spread out on a reel to dry.

Under certain conditions special methods of seining are regularly

1. Carp fishing near mouth of Sandusky River.

2. Seining carp from pound at Squaw Island, Sandusky River.

3. Seine boat and live-car, Sandusky River.

4. Preparing carp for smoking, Sandusky, Ohio.

THE CARP FISHERY OF LAKE ERIE.

employed. For example, some of the marshes connected with small tributaries of the Sandusky River open into the main channel by outlets so definite that any fish which happen to be in the marshes can be shut off from the river simply by setting a seine across these outlets. As has already been explained (p. 558), on account of the varying direction and force of the winds over Lake Erie the water level is almost constantly changing, affecting also the level of the waters of the bays, rivers, and marshes. By experience the fishermen have learned that when the current sets up and the water level is rising, the carp work up the streams and spread out over the marshes. Conversely, with the fall of the water they move out of the marshes again into the deeper waters. So careful watch is kept of the currents, and shortly after the water has reached its highest, and is beginning to go down again, a seine is stretched across the outlet from the marsh, as described above. A row of stakes is placed in a semicircular line on the downstream side of the seine to prevent its being carried away by the force of the outgoing current, and the cork-line is made fast to each of these stakes, so that the net will not be carried away if the current should change and set upstream again. As the water recedes the carp crowd on the upstream side of the net in large numbers, and when the fishermen decide that enough have come down to justify it, the haul is made. If the current is still running out, a second seine is often set immediately in the place of the first. The fishermen can get some estimate of the number of carp that have gathered above the seine by the number that are seen splashing, or by running a paddle slowly through the water, when, if there are many fish present, they can be felt to bump against the paddle. To make the haul, a brail rope is carried across upstream from one side to the other, and the net is wound in to one shore in the usual way.

An outfit for seine fishing, including seine boat, seine, lines, and other accessories, represents an outlay of about $150 to $200. In other words, a capital of $40 to $50 each is required where the crew consists of four men. Some crews, consisting, perhaps, of only two or three men, who work on a smaller scale, are probably able to outfit for a smaller sum. In some cases the outfit is furnished by a wholesale dealer or fishing company, and the fishermen work on a salary or on a percentage of the value of the catch.

The time ordinarily required to make a seine haul and dispose of the fish is from one to two hours, though it may vary with conditions, and the haul is not considered to have paid unless at least half a ton of fish is taken. As a rule, the fishermen will not make a haul unless they think there is a chance of getting a greater amount of carp than that. The number of fish which may be taken at one time depends in large part upon the season, and the size of single hauls sometimes made during the spring months is almost incredible. Upon what appeared to be reliable information there were reported to me a num-

ber of hauls in which 10 tons of carp were taken at one time. It would probably be fair to assume that these fish taken in the spring averaged in the neighborhood of 8 pounds each, which would mean that each haul contained some 2,500 fish. The largest single haul of which I heard at Lake Erie was said to have contained 14 tons of fish. A recent apparently well-authenticated report from Lake St. Clair, however, exceeds this by more than as much again. Net fishing in Lake St. Clair has been prohibited by the state of Michigan until within a short time, and in the favorable marshes of the St. Clair delta and about the mouth of the Clinton River the carp had increased to an amazing extent, resulting in some phenomenal hauls now that seining for these fish is permitted. The American Fish Culturist for July, 1904 (vol. 1, no. 7, pp. 18–19), quotes from the Detroit News an account of probably the largest haul on record, and adds further confirmation of the report from Mr. Seymour Bower, superintendent of the Michigan state hatcheries. The article seems of sufficient interest to quote in full:

"That despised fish known as the German carp is having a growing commercial value, and with the possibilities of carp fishing in mind, Carl Schweikart formed two companies, the St. Clair and Erie Carp Company and the Detroit Carp Company. The field of operations is at the mouth of the Clinton River, where the water is clear and the fish are supposed to be at their best. The former company has had phenomenal success in carp catching, having taken in one haul last week 7,200, which they suppose will average about 8 pounds. The catch was made about 8 o'clock in the morning, and several men were kept busy all day getting the carp out of the nets and into the ponds in which the carp are kept until sold. Eastern buyers are figuring for the purchase of their entire catch, but Mr. Schweikart is inclined to wait for better prices. The quotation in New York is now 3 cents a pound.

"What do they do with the carp? Well, they are considered a delicacy by hundreds of patrons of the best hotels and cafés in the East, but the name 'Great Lakes salmon' is preferred."

Referring to the above, Mr. Seymour Bower, superintendent of the Michigan State hatcheries, says:

"The big haul was made in Lake St. Clair, near the mouth of Clinton River. Net fishing of all kinds was prohibited in this lake until the last legislature passed an act allowing the seining of carp. This lake, as you may know, is famous for its smallmouth bass fishing, and it is claimed that the presence of the carp in such overwhelming numbers is bad for the bass; hence the passage of this law."

"Mr. Schweikart is interested in two companies fishing for carp, and I supposed that report of the catch for the month of May, received a few days ago, covered everything in which he was interested, but it was for one company only. The report for the other company was received this morning, and the big haul is there all right. I then called Mr. Schweikart by 'phone and he not only confirms the statement made in the clipping, but says the half was not told, and I know Mr. Schweikart is thoroughly reliable. He states that from the big haul they impounded 7,200 carp by count, and for want of time and facilities for handling were obliged to let fully as many more go, and that the fish taken will average not less than 10 pounds in weight. The two companies in which he is interested impounded 44,900 carp by count in May, or upward of 200 tons.

"Following are the rules under which eleven firms are now fishing there:

"RULE I.

"No person shall catch German carp in any manner except with hook and line, without first notifying in writing the State game warden and the State Board of Fish Commissioners, at their office in the city of Detroit, of the time and place where he intends to fish for carp.

"RULE II.

"No person shall catch or take German carp from said waters except with a seine with a four-inch mesh extension measure as used, and with a hook and line. No person shall catch or take German carp with a seine without first giving a good and sufficient bond conditioned for the faithful observance of these regulations and for the payment of a penalty of fifty dollars ($50) for each and every violation of these rules and regulations.

"RULE III.

"If German carp which are caught are to be kept for future sale, shipment, or delivery, a pond or other suitable inclosure shall be prepared in which said carp shall be placed and kept, and the State game warden and the State Board of Fish Commissioners shall be forthwith notified in writing of the location of such pond or inclosure. Said pond or inclosure shall at all times be open to the inspection of the said game warden, or any of his deputies, and to the inspection of the State Board of Fish Commissioners, or to the inspection of any person appointed by said board for the purpose of inspecting said carp and the manner of fishing therefor.

"RULE IV.

"When any such German carp are killed and sold, shipped, or delivered, the owner or shipper shall make duplicate invoices of the same, one of which shall forthwith be delivered or mailed to the State game warden, or to such person and to such place as he may designate, and the other shall accompany the package of carp so sold, shipped, or delivered. Said invoice shall truly state the time and manner of shipment; by and to whom consigned, sold, or delivered. Every fisherman who shall engage in business of catching German carp shall once a month make a report to the State Board of Fish Commissioners, which report shall contain a true statement of the quantity in pounds of the daily catch of German carp made by him during the month. Said report shall be mailed or delivered as aforesaid on or before the fifth day of each month.

"RULE V.

"Every package of German carp sold, shipped, or delivered shall be plainly marked so as to show what it contains. It shall also show by whom same is sold, shipped, or delivered, and such package shall contain no other kind of fish whatever.

"RULE VI.

"When any other kind of fish than German carp shall be caught or taken in the seine prescribed by law and by these regulations, the same shall be carefully put back in the water and, under no circumstances, kept by the fisherman.

"RULE VII.

"Whenever a special inspector shall be required to watch the taking, killing, or shipping of German carp by any fisherman, the expenses of said inspector, not exceeding three dollars per day, shall be borne by such fisherman.

"The right to amend and alter these regulations at any time is especially reserved by the State Board of Fish Commissioners, and will for each violation of any of the laws of Michigan with reference to the protection of fish, pay to the State Board of Fish Commissioners the sum of $50, then this obligation is to be void, otherwise to remain in full force."

The laws governing the taking of carp in Lake St. Clair are quoted to show what can be done in cases of this kind to allow of the utilization of the carp, to decrease their numbers, if that seems necessary, and still to afford protection to the native fish, especially the game fish, such as the black bass.

OTHER METHODS OF CAPTURE.

The number of carp taken by other means is insignificant as compared with that taken by seining—in fact, it is seldom that any other kind of net is set exclusively for carp. Small numbers are taken more or less regularly in the pound nets set in Lake Erie for saugers and pickerel (wall-eyed pike) and for white-fish, as well as in the traps and fyke nets set in the bays and rivers for other species of fish. A few carp—mostly small ones—are obtained in the gill nets set for white-fish about the Bass Islands in the fall. Occasionally when a number of carp have entered some place where a net can be set across their only way of escape, or where they can be driven into it, a gill net is used. Thus if carp are frightened out of the rushes where they are feeding they will usually make directly for deeper water. If a gill net is set so as to intercept them many will rush into it and become entangled; but they are such vigorous fish that unless the net is an exceptionally strong one they are apt simply to tear it to pieces. I believe trammel nets have been tried in the same way, but not with enough success to warrant their general use.

PACKING AND SHIPMENT.

The method of transportation of the fish to the fish houses has already been mentioned (p. 611). The fishermen may dispose of them immediately after they are caught, or they may keep them for a time pending a rise in the market price. In the latter case the carp are retained in pens or ponds as will be described later. The fish are received at the wholesale houses often in a living condition, although they may have come a distance of several miles packed a foot or two deep in a wagon or boat. They are transferred from the boats to boxes by means of short-handled dip nets, the iron frames of which are usually straight on the side opposite the handle, a construction which facilitates using them to take fish from the bottom of a boat. The boxes are now slid inside the fish house and placed on the scales where the fish are "weighed in," and are then dumped out in a pile on the floor. Usually no record is made of the number of fish, but all measurements are by weight. As soon as possible the fish are packed into plain lumber shipping boxes of uniform size and especially made for this purpose. A box is placed on the scales and chopped ice is shoveled in until it tips a certain weight; a 150-pound weight is then added, and carp are shoveled in until it is balanced. For handling the

fish when they are on the floor ordinary large scoop-shovels are used. Each day the boxes of carp are shipped either by freight or express to the large cities, where they are in demand. From the fact that some of the fish from Lake Erie at times reach New York still in a living condition, it will be seen that there is no need that the fish should be cleaned before shipment, even did not the consumption of the greater portion by Jews demand that they be shipped "in the round."

Some firms, when the supply of carp exceeds the demand at the time, freeze a part of the catch and hold them over in this way, but the frozen fish do not find so ready a sale.

EXTENT OF THE FISHERIES.

The amount and value of the carp output of Lake Erie has been steadily on the increase for the past eight or nine years. The fish first began to be handled by the dealers in about 1890 or 1891, but had no extensive market until about 1895. At a fish house in Port Clinton it was stated that when they first began to be taken they were thrown in with the mullets and sold at 1 cent a pound, and the dealers did not want them at that price. They were then put on the list as German carp, at 3 cents, and at once found a ready sale.

That the fishery had not become established in 1892 is shown by the fact that carp are not mentioned under the "Products of Lake Erie fisheries," in the Report of the United States Fish Commission for that year (p. cl), nor in the paper by Smith in the same report on the fisheries of the Great Lakes.[a] They were being used more or less in other places, however, and Smith (1898, p. 494) estimates the amount of carp taken in the waters of the United States, exclusive of the Great Lakes, in 1894, as 1,448,217 pounds, valued at $37,683. The catch from Illinois was more than four times that from any other state, Iowa coming next. The Lake Erie fisheries had increased enormously by 1899, and Townsend (1901) in reporting for that year says (p. 178):

> The catch of carp in Lake Erie in 1899 amounted to 3,633,679 pounds, valued at $51,456. The report of the Illinois Fishermen's Association shows that the catch of carp in the Illinois River is greater than that of all other species combined, the quantity of carp taken in 1899 amounting to 6,332,990 pounds, valued at $189,980. The yield of carp from the Ohio River and two of its tributaries, the Cumberland and Wabash rivers, during the same year, amounted to 113,387 pounds, worth $6,654.
>
> These figures show an increase in the quantity of carp derived from the above-named waters amounting to nearly nine times the quantity yielded six years ago.

[a] Although the Lake Erie and Illinois carp fisheries had not become established at this time, these fish from eastern waters were finding a ready sale in the New York markets. This is shown by the following statement of Mr. John H. Brakeley (1889a): "I have sold several hundred pounds of carp during the past autumn in the New York market, the commission merchants getting 15 cents a pound for them. I am satisfied that it will pay to feed carp, and shall do considerable of it next season."

In the summer of 1901 I myself visited all the principal fish dealers on Lake Erie, and made as accurate an estimate as possible of the extent of the carp fishery for the calendar year 1900. A number of factors prevent great accuracy in such an inquiry; for example: (*a*) Some dealers keep no record whatever of the carp handled by them; (*b*) others keep record only of their own catch, not recording those bought by them from fishermen; (*c*) in some cases the carp are weighed in and sold with the suckers, and (*d*) it sometimes happens in the spring that carp come in faster than they can be handled, when the surplus is weighed up with the refuse, and sent to the fertilizer factories. In spite of this, however, it is felt that the following statistics give a fair estimate of the total amount of carp shipped from Lake Erie in 1900:

	Pounds.
Detroit, Mich	300,000
Monroe, Mich	14,000
Toledo, Ohio	432,548
Port Clinton, Ohio	2,361,723
Sandusky, Ohio	1,260,817
Total for western end of lake	4,369,088
Huron, Ohio	14,168
Vermilion, Ohio	3,561
Lorain, Ohio	20,773
Cleveland, Ohio	16,000
Ashtabula, Ohio	2,500
Erie, Pa	12,000
Buffalo, N. Y	160,000
Total for eastern end of lake	229,002
Total for lake	4,598,090

The price paid to fishermen for carp varies from about 30 cents per 100 pounds in the spring months to 2½ cents per pound in the winter. Taking 1½ cents per pound as a fair average, the value of the carp catch of 1900 would be $68,971.35. This is an increase of 964,393 pounds over the catch of 1899, and an increase of valuation of over $17,000. As nearly as could be judged at the time, the catch for 1901 promised to be about as much larger than that of 1900. No accurate statistics have been gathered since that time, but the fishermen say that the fishery is still increasing.

The number of pounds of carp taken in Lake Erie in 1899 equaled nearly one-sixteenth of the total catch of fish of all kinds in the lake for that year, while the value was about one twenty-second of the entire fisheries product.

In the Mississippi River and the streams tributary to it, especially in the Illinois River, the carp fisheries are of far greater comparative importance, and for several years carp have constituted over one-half of the total yield of the fisheries of the last-named stream (Townsend,

1902, p. 150). In 1899 the catch for these streams was 11,869,840 pounds, valued at $289,258. In a letter dated October 19, 1903, Dr. S. P. Bartlett states that the value of the output in 1901 from the Illinois River was nearly two-thirds of a million dollars, 17,000,000 pounds being the output;[a] and in a previous letter—

> I am safe in saying that of all the fish produced in our inland waters and rivers the carp will bring the fishermen more money than all their other catch.

ANGLING.

The anglers for trout and bass naturally look upon the carp with great contempt. Nevertheless there are those who are ready to champion the foreigner, and some would even rank him as a game fish. In Germany, angling for carp in the open waters has afforded recreation, and has been a not unimportant factor in the food supply of the people; and in England carp have been sought by the angler since their earliest introduction into that country. They are mentioned among the fishes included in the treatise on angling in the "Boke of St. Albans," first published in 1486, and consisting of a number of compilations often attributed to Dame Juliana Barnes (or Berners), though the section on angling was probably not written by her. This account is interesting as being probably the earliest record we have of the carp in the English language; and being brief, may well be quoted here:

> The carpe is a deyntous fysshe: but there ben but fewe in Englonde. And therefore I wryte the lasse of hym. He is an euyll fysshe to take. For he is soo stronge enarmyd in the mouthe that there maye noo weke harnays holde hym. And as touchynge his baytes I haue but lytyll knowlege of it. And me were loth to wryte more than I knowe & haue prouyd. But well I wote that the redde worme & the menow ben good baytys for hym at all tymes as I haue herde saye of persones credyble & also found wryten in bokes of credence.[b]

In the later English writings on fishing, the carp is accorded a prominent place, and Izaak Walton (1901 ed.) devotes a chapter to its natural history and the modes of capture. He styles it "the queen of rivers; a stately, a good, and a very subtile fish," and says (p. 17):

> And my first direction is, that if you will fish for a Carp, you must put on a very large measure of patience, especially to fish for a River Carp: I have known a very good fisher angle diligently four or six hours in a day, for three or four days together, for a River Carp, and not have a bite.

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[a] It would seem that Doctor Bartlett has put the valuation rather high. Two-thirds of a million dollars for 17,000,000 pounds of fish would mean a value of slightly over 3.8 cents per pound. At the same rate used in estimating the value of the Lake Erie catch above (1¼ cents) the Illinois River catch for 1901 would be worth $255,000. If we estimate the Lake Erie catch for 1901 on the basis of the catch of 1900 over that of 1899 (an increase of nearly a third) it would amount to approximately 5,800,000 pounds, with a value of $87,000, making a total of 22,800,000 pounds, worth $342,000 for the two regions. There are no data at hand for estimating the amount of carp caught in other parts of the United States, but it is probably comparatively small in proportion to that for the regions given.

[b] From a reprint of the Wynkyn de Worde edition of 1496 (London, 1810, treatise of "Fysshynge with an angle," signature i j).

He then goes on to tell when one should fish, the kinds of bait that should be used, and ends with an elaborate recipe for its cooking.

Perhaps the best directions for fishing for carp with hook and line are those quoted from Pennell by Goode (1888, p. 414) in his popular treatise on American Fishes.

Early in the morning, and, occasionally, late in the evening, are the best times for fishing; but, as observed, the catching of Carp with the rod and line is always a difficult and uncertain operation, particularly if the fish are large. The smaller the pond, the better the chance I have always found of catching Carp and Tench, though, of course, they are not so large as in bigger waters. I once caught a bucketful of Carp before breakfast, in a pond by the side of a road between Weybridge and Byfleet, which was not bigger than an ordinary sized ball-room. The biggest of these Carp did not, however, exceed 2 pounds in weight.

The following is the method of Carp fishing in stagnant waters which I have found most successful:

Let the line be entirely of medium sized or fine round gut—clouded, if possible—with a very light quill float, say No. 4, and one good-sized shot, about 6 inches or so from the hook, which should be No. 5 or 6 and baited with a brandling or red worm. Plumb the depth accurately; and arrange the distance between the float and the shot, so that the latter may exactly rest on the bottom, weighing down the point of the float to about "half-cock," and letting the gut below the shot and the bait lie on ground. Fix the rod in the bank and keep perfectly quiet. When a bite is perceived, do not strike until the float begins to move away.

It constantly happens, however, that the Carp will not be taken either by this or any other mode of fishing with which I am acquainted; but if he is to be caught at all it is thus.

The baits are, worms (first), gentles, greaves, grains and various sorts of pastes, of which latter, however, I believe the plain white bread crumb paste is the best, as well as the most easily made. Professor Owen, who had a good deal of Carp fishing experience in Virginia water, gave me the results of his practice which concur in a great measure with my own, except that he fished with his bait paste made of soft herring roe worked up with bread crumbs and wool, a favorable substitute sometimes for the brandling.

In Germany the "angler usually prepares for his sport by 'ground-baiting' with a thousand or more angle-worms, twenty-four hours before he expects to fish, and while fishing he throws worms into the water."

While most of our sportsmen would probably indignantly object to having the carp classed as a game fish, it must be admitted that whether it should be so classed or not depends largely upon our definition of a game fish, and, as Goode says (1888, p. xiv), "no fish which is not of the highest rank as a table delicacy is rated by Americans as a game fish." He continues:

The barbel, the dace, and the roach, the pets of the father of angling, classical in the pages of sportsmen's literature, are despised by new world authorities, and are now considered "coarse fish" even by English writers. Yet they afford excellent sport—sport which in England tens of thousands enjoy to every one who gets the chance to whip a salmon or trout line over preserved waters.

And so it is with the carp. Those who live where there is an abundance of other fish, such as bass and pickerel, or even of perch and

bream, will probably not abandon those fish for the pursuit of the carp, while, on the other hand, those who have done most of their fishing for buffalo, red-horse, mullet, or bull heads should welcome the carp with joy. How far in this country its capture is supplanting, or at least supplementing, the other of the coarser fishes in this respect has been best told by Dr. S. P. Bartlett (1903), of Illinois. For this reason I quote the greater portion of his paper:

The question has been asked me a great many times why it was that carp can not be taken with the hook and line. A great many persons have told me that they have used all kinds of bait and failed to get them to take it. These inquiries came to me as a surprise from the fact that hundreds daily fish for carp with hook and line on Quincy Bay and all along the Illinois River with great success.

I have found the best bait to be a dough ball made by boiling cornmeal to a good stiff mush, and then working the ordinary cotton batting into it until it becomes hard and stiff, and then rolling into little round pellets about the size of a marble. Bait prepared in this way will not be easily dissolved by the water. I use the ordinary Carlisle hook fastened on the end of a good strong line and three or four inches above the hook, attach quite a heavy sinker which will take the line to the bottom and allow the bait to flow up away from the bottom. Another good bait is the ordinary ship stuff from the mills, boiled stiff and dough rolled out in sheets and then cut up into little squares, perhaps three-fourths of an inch square. Fried potatoes, sliced raw and fried until they become stiff, not brittle, also is a fine bait. Anyone conversant with the hook and line at all, will have no trouble in carp if this bait is used as indicated.

On Quincy Bay I have seen as many as two hundred people fishing for carp along the shores, and nearly all of them get good fair strings. The carp when hooked is a very vigorous fighter, and care must be used that he does not break the hook or break out the hook from his mouth. I would advise the use of the landing net. They are daily taken on trout lines, using the same kind of bait.

Since your request for information as to the carp from an angling standpoint, I have given the matter a great deal of attention, and have been greatly surprised at the extent to which carp are caught with hook and line. From Cairo to Dubuque on the Mississippi River I have found shores at all the towns lined with people fishing for carp, all catching them. One day last week, from the lower end of Peoria, Illinois river, to water works point, a distance of three miles, I counted 1,103 people fishing with hook and line, and on investigation [it] developed that a large per cent of them were taking carp. The majority of those caught weighed a pound and as heavy as five pounds, all of them probably used as food. Permit me to introduce here a letter from one of the best known sportsmen in the State [Mr. M. D. Hurley, of Peoria, Ill.]:

"Carp fishing with hook and line has now taken its place with bass and other kinds of fishing. All along the river in this locality carp are being caught freely with hook and line this year, and to say they are gamey, is not half expressing it. For the past month I have made it my business to go along the river and take notes of this particular kind of fishing and talked with no less than 25 different persons who were busy catching carp, and in every instance I was told it was rare sport to hook a carp, as it was quite as much of a trick to land one as it was to land a bass; dip nets were used generally to land the carp, as the activity of the fish when jerked out of the water would tear the gills and free the fish quite often. The bait used when fishing for carp is dough balls and partly boiled potatoes, the latter being best in the opinion of the majority. The carp will bite on worms quite freely also, and in two instances, I found carp had been taken with minnows, something that has been considered impossible heretofore, but in these two cases I am certain it was

done, as I have the names of the parties who caught the fish. An old German who lives here goes daily to the river with a regular fly casting pole and reel to fish for carp. Of course he exchanges the fly for the regulation hook, but he used his reel in landing the carp, and says there is no finer sport than fishing for carp. This man uses partly boiled potatoes altogether and is very successful in taking carp in numbers daily. I have caught a great many carp myself with hook and line, using potatoes, dough balls and worms, and found that the partly boiled potatoes worked best, as the carp seemed to take that particular bait when they would not bite any other. As for the sport of catching carp with hook and line, I consider it equal to anything in the way of pleasure fishing, as the fish is gamey and will fight as hard against being landed as bass or other game fish and is to be handled with precaution on account of the tender gills, which will often tear when hooked by an inexperienced angler. In the past two years carp have become popular where they were unpopular, because of the wearing away of the prejudice that they were of no benefit to the angler on account of the belief that they would not take a hook. Now it is different, as the very ones who were so loud in their protest against the carp, have found great sport in taking them with hook and line, and it is wonderful to hear the change of sentiment as to the carp for food purposes. They are a good fish now and fit for a king in comparison to what was said of them while the prejudice still existed. To my mind the carp is a good fish for food purposes and is fast finding favor in the west in every way, now that the angler has found it is the coming fish for sport. Just at present, in the Illinois river, we have a world of all kinds of game fish and no end of carp, which insures the angler his full measure of sport until the end of time."

At Detroit and at Put-in Bay I have seen numbers of persons fishing from the wharves with hand lines for carp. The bait in most general use was a piece of boiled potato wrapped in mosquito netting to keep it on the hook. On the 25th of July, 1901, with this bait, I saw taken from the steamboat wharf at Put-in Bay a carp which measured 31.5 inches in length and the weight of which was estimated at about 16 pounds. This fish made a vigorous fight, and would have taxed the ingenuity of an expert angler if he had hooked it on a trout line and a light rod.

There is a tendency among sportsmen to deny the title of game fish to any that will not rise to a bait, either real or artificial. In such a category the carp certainly can not be included; it must be classed rather with those fishes that reward the quiet, "contemplative" angler, who must wait patiently until the fish bites, but who then has the same problem and must exercise the same skill in landing his game that he would have to display had he hooked one of those species generally acknowledged to be game fishes.

CARP CULTURE.

Carp ponds and pens may be divided primarily into classes according to the purposes for which they are used: (1) Permanent ponds or complements of ponds, used for breeding, rearing, and retaining the fish until such time as they are large enough to dispose of in the market; and (2) temporary ponds or other inclosures used only for holding carp from times when they are easily obtained until, on

account of their scarcity, the market value has risen to a point making their sale profitable. The terms permanent and temporary are thus used here, as it will be observed, not in the sense of the time of duration of the ponds, but as denoting the manner in which they are used. The latter sort correspond more or less closely in their function to the stock ponds on a well-equipped German carp farm. Either sort may be natural or artificial.

PERMANENT PONDS.

With a few possible exceptions carp culture has never been attempted in this country after the lines on which it is carried on so extensively in Germany. Most of those persons throughout the United States who aspired to carp culture at the time these fish were being distributed by the Government merely dumped the fish into any body of water that was convenient, or into any pond that could be hastily scraped out or constructed by damming some small stream, and thereafter left them to shift for themselves, possibly feeding them occasionally at first. That such efforts were not a success is no more to be wondered at than would be a man's failure if he attempted to establish a successful poultry farm merely by turning a few dozen fowls loose in the neighborhood of his home. Whether extensive and properly conducted carp farms would then, or would now, be profitable and pay a reasonable return on the capital and labor invested, is another matter, and will be considered a little farther on.

It is not proposed here to enter into an elaborate description of the methods employed by the successful European carp culturist. American readers who may be interested in the subject are referred to the excellent paper by Hessel (1881), which has been cited frequently throughout this report, and to the fuller account given in the translation published by the United States Fish Commission of the work by Nicklas (1886). Numerous works on the subject have been published in German, and references to them will be found in the bulletins named above; among the more recent books may be mentioned those by Susta (1888) and Knauthe (1901).

Some idea of the extent to which carp culture is practiced in Germany and the neighboring parts of Europe may be gained from the following extract quoted from Hessel (1881, p. 866):

> A celebrated establishment for carp-culture, with large, extensive ponds, was located, as early as the fourteenth century, near the town of Wittingau, in Bohemia, Austria. The first beginning of it may be traced back to the year 1367. At that time the lords of Rosenberg called into existence and maintained for centuries these establishments on a scale so extensive that to this day they are the admiration of the visitor, the main parts having survived, while the race of the Rosenbergs has long been extinct.
>
> The manor of Wittingau suffered greatly from the calamities of the Thirty Years' War, and with it, in consequence, its fish-culture. The latter only recovered the

effects of it after passing, together with the large estate of a rich monastery of the same name, in the year 1670, into possession of the Princes of Schwarzenberg, their present owners. The extent which carp-culture has reached on these princely domains will be seen from the circumstance that their artificial ponds comprise an area of no less than 20,000 acres. The proceeds amount to about 500,000 pounds of carp per annum. The ponds of the Princes of Schwarzenberg are probably the most extensive of the kind on the globe. They are usually situated in some undulating lowland country, where small valleys have been closed in by gigantic dams for the purpose of forming reservoirs. Similar establishments, though not equally extensive, are found in the provinces of Silesia and Brandenburg; as, for instance, near Breslau and Cottbus, in Peitz and Pleitz, which I visited last year. In Hesse-Cassel, Hanover, Oldenburg, Mecklenburg, and Holstein there are also many hundreds of ponds, none of them covering more than a few acres, but almost every large farm possessing at least one of them.

The well-appointed carp-cultural establishment has at least three kinds of ponds, each adapted for a particular phase of the industry. These ponds are usually made by throwing dams across small valleys, and by the aid of dikes, and are commonly fed by small streams flowing into them, by springs, or they may depend entirely upon the rains to keep them filled. These last are often spoken of as "sky-ponds," and are much more uncertain than the others. The ponds fed by streams are ordinarily protected from flooding by freshets by leading the main channel of the stream around them, so that the amount of water which flows into the pond can be regulated at will.

The classes of ponds are:

1. Spawning ponds. Shallow ponds in which the water is easily warmed by the sun, and suitable for the spawning fish.

2. Raising ponds. Ponds, usually of medium size, to which the fry are transferred and where they are retained, isolated from the larger fish, until they are a year or two old.

3. Stock ponds. Large ponds in which the fish are kept until they have reached a marketable size; this is usually considered to be when they have reached a weight of 2¼ to 2½ pounds. One reason that the young fish are reared for a time in the raising ponds is that in the stock ponds with the older carp are often kept a number of predaceous fish, such as perch, pike, etc., which are supposed to keep the carp in better condition by preventing them from becoming too lazy and sedentary. These fish would destroy the carp fry if the latter were put into the stock ponds while still small. The predaceous fish also form a secondary source of income.

Since the stock ponds are not always favorable for the wintering of the fish there are sometimes ponds especially adapted for this, and these are known as—

4. Winter ponds. These should be in sheltered localities, if possible, and should have a depth of at least 6 to 8 feet.

All the above classes of ponds are constructed upon the same general principle. Ditches from the various parts of the pond lead into other

ditches which are deeper, and these finally lead into a still deeper pit (the "fish pit"), which is situated at the place of outlet, usually near the dam. When it is desired to drain the pond, the water is drawn off gradually, the fish work down into the ditches, which completely drain the pond, and so they all come finally into the fish pit, whence they can be taken with nets. In a properly constructed pond it is possible to draw all the water from the pit, and thus completely drain the pond. It is common on many farms to have a curious "rotation of crops;" the fish ponds are drained and turned to agricultural purposes for a season or two, when by closing the outlet gates and allowing the water to fill them again they are reconverted into ponds, and pisciculture is resumed. Such a proceeding is said to have a salutary effect upon both industries.

TEMPORARY PONDS AND PENS.

Although there are very few, if any, carp-cultural establishments in this country conducted on the principles of those that have just been described, there is, nevertheless, an increasing number of ponds being constructed and used for the temporary retention of the fish. This is true especially in the Lake Erie district. These inclosures vary all the way from the simplest pens, not calculated to hold more than one-half ton to a ton of carp, to extensive ponds covering large areas and constructed and maintained at a considerable expense.

These temporary inclosures may again be divided into two classes: (1) Those in which the level of the water is not under control, but varies with the changing level of the surrounding waters; and (2) those in which the water level in the ponds can be artificially maintained at any desired height.

Under the first class the simplest kind is that already mentioned (p. 612) as being used when it is desired to retain the fish only a very short time—a few days to a week or so at most. These are the ordinary live-cars or crates—large boxes constructed of rough boards with cracks between, which allow the access of plenty of fresh water. When the fish have been placed in these, the covers are fastened down and the cars towed out to where the water is deep and certain to be fresh—well out in a stream, if possible. The cars are weighted with heavy stones, so that they float with their tops just at the surface of the water. Fish kept in cars are seldom fed, unless it is necessary to keep them much longer than is usually the case. When they are taken out, dip nets are employed.

A common method of constructing inclosures which will accommodate a larger number of fish, and in which they may be kept indefinitely, is to build out into a stream, or from the shore of a bay or lake where the conditions are suitable, a sort of rough picket fence around three sides of an area, the shore usually forming the fourth

boundary (fig. 2, pl. II).[a] This fence consists of rough boards driven into the mud a short distance apart, and supported at intervals by strong stakes driven firmly into the bottom. It is necessary to have the top of the fence several feet higher than the highest water, to prevent the fish from leaping out. A woven-wire netting 2 to 3 feet high is often added to the top of the fence for this purpose; it is not practicable to use the wire netting under the water, as the fish would become badly bruised in attempting to get through it, or by dashing into it without seeing it. The pens may be of any size, from small ones, which will accommodate only one or two hundred fish, to those covering an extent of some 2 or 3 acres. Larger ones than this are probably not practicable on account of the difficulty that would ensue in attempting to get the fish out of them; obviously the water can not be drawn off and the pen drained, so the only way of taking the fish is with a seine. This is done by setting the seine around the perimeter of the area, close to the fence, and then hauling it to one corner of the inclosure, where the fish can be gathered into the bag of the seine (fig. 2, pl. II).

As a rule there is not enough natural food in these pens for the sustenance of the fish, and in order to keep them from falling away greatly in weight it is necessary to supply them with food. The necessity of removing the fish with a seine makes it impracticable to build the pens where there is plenty of vegetation to supply the fish with natural food, since much vegetation would interfere greatly with the seining.

Pens should be built in places sheltered as much as possible from storms, for the high waves are apt to break down the fence and allow the fish to escape. Unusually high water and severe storms caused great damage in this way in Sandusky Bay and vicinity in the summer of 1902, one pen, in which there were said to be 40 tons of carp at the time, being broken down in places so that all the fish were lost.

Portions of marsh which have comparatively narrow openings leading into them are sometimes converted into ponds by throwing embankments, or more often building board stockades, across the narrow places. Such ponds usually have the advantage of containing plenty of natural food, but trouble usually arises when it comes time to take the fish out, as the places are not adapted to the use of a seine. In some cases the embankment or fence, with a convenient gateway, is constructed early in the spring and the gateway is left open until a large number of fish have entered the shallow water of the inclosure for the purpose of spawning, after which the gateway is closed and the fish are entrapped, to be seined out at leisure. At one or two places great areas of marsh were cut off in this way and the fish were prevented from returning to the larger open waters; but this was of

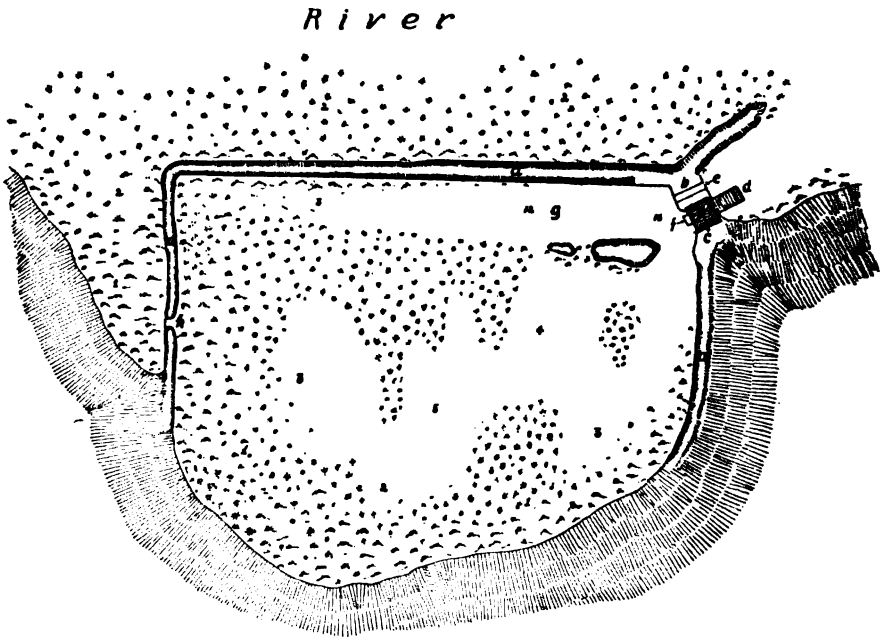
[a] A photograph of a carp pen similar to this is shown in the Illinois fish commissioner's report for 1900-1902.

little avail, since the places were so large and the conditions so varied that it was practically impossible to get the fish out.

There remain still to be considered those ponds in which the water can be maintained at a definite height irrespective of the varying level of the neighboring waters. Under suitable conditions they could probably be constructed best in valleys and natural depressions according to the plans already outlined as being in general use in carp-cultural establishments. Under the conditions of our fisheries, however, it is a matter of great economic importance that these ponds should be as near to the fishing grounds as possible, and as the land there is low and marshy the ponds must for convenience be constructed in or along these marshes. For this reason the problems presented are very different from those met with in the building of ponds on higher ground. The greatest difficulty comes, of course, in the matter of the drainage of the pond, since its deepest portions of necessity lie below the level of the outside waters. An idea of the methods that have been devised can probably best be conveyed by giving brief descriptions of two or three ponds which have now been in use for several years.

Along the marshy shore of the Portage River, a mile or two above Port Clinton, Ohio, is a successful carp pond covering some 30 to 35 acres, and owned and managed by two brothers, who also conduct at the same time a fruit farm immediately adjacent to the pond. The site of the pond was originally a marsh, flooded by backwater from the river, where the carp commonly came in to feed and to spawn. It was first converted into a pond (see diagram, p. 628) by throwing up an embankment along the river side, cutting it off from the river, but still leaving it connected by an open gateway protected by a screen or grating. The inclosed water was at the same level as the outside water, and as the level rose and fell a stream rushed in and out through the gateway. This plan was found to be unsatisfactory, as the impounded fish crowded about the grating, neglecting to feed, and at the same time becoming badly bruised by their contact with the bars. The embankment was then raised and the gateway closed, so that the water in the pond could be maintained at a level 1 to 2 or 3 feet or so higher than the mean level of the river, while at the same time the increased height of the water caused it to spread farther back over the land, enlarging the pond, and encroaching upon a neighboring cornfield, a large portion of which was thus converted into marsh. The principal embankment was easily raised by having a shovel-dredge make a cut along the inner side, the excavated mud being deposited on the outer side of the cut to form the embankment. The lower portions were built with a scraper at a time when the river was especially low, at which periods the pond can be practically drained of water. During rainy seasons springs kept the water well up to the desired

level, but during drier times these were not sufficient, and it became necessary to pump water in from outside. This was done for a season or so by means of an "elevator" in a wooden trough or chute in which run endless-chain belts with closely fitting boards forming a series of buckets as they move upward through the trough. (See fig. 2, pl. III.) The motive power at first was a span of horses, but later a 7-horsepower gasoline engine was installed, which does the "pumping" or elevating much more expeditiously. The amount of pumping required to keep the water at the proper height and sufficiently fresh



Diagrammatic plan of carp pond near Port Clinton, Ohio: *a*, embankment; *b*, dam; *c*, engine-house; *d*, water elevator; *e*, chute through which fish are slid into pond; *f*, chute through which fresh water enters pond; *g*, dredge-cut; *h*, outlet. The figures indicate depth of water.

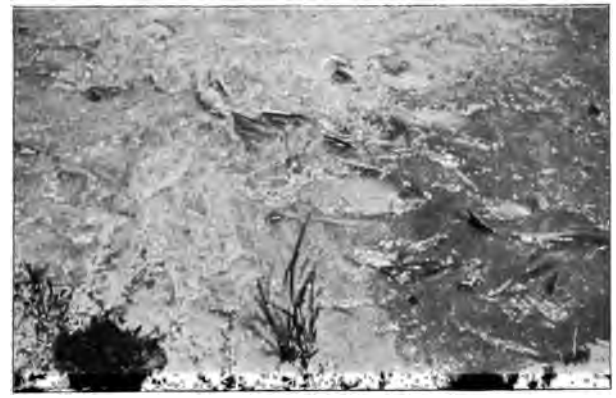
depends very closely upon the weather conditions and to some extent upon the number of fish in the pond. It is seldom that so much as two or three hours a day is required.

The water in the dredge cut is about 12 feet deep, but in other portions of the pond there are few places more than 5 or 6 feet in depth, and much of the water is considerably shallower. In all the shallower parts is a rank growth of aquatic vegetation (sweet flag, cattails, deer's tongue, wild rice, bulrushes, burr reed, etc.) which supplies so much natural food that the fish are seldom or never fed artificially. With the maintenance of the water level, thus avoiding the rushing of the water in and out through a grating, the fish remain distributed most of the time throughout the marshy parts of the pond

1. Dam and engine house of a carp pond at Port Clinton, Ohio. Carp are slid into the pond from the chute on the left; fresh water is received from the chute on the right, which comes through the engine house.

2. Outer side of dam, showing engine house and elevator in operation. Same pond as in figure 1.

3. Supplementary engine and elevator for carrying water from dredge cut to pond, Monroe, Mich.

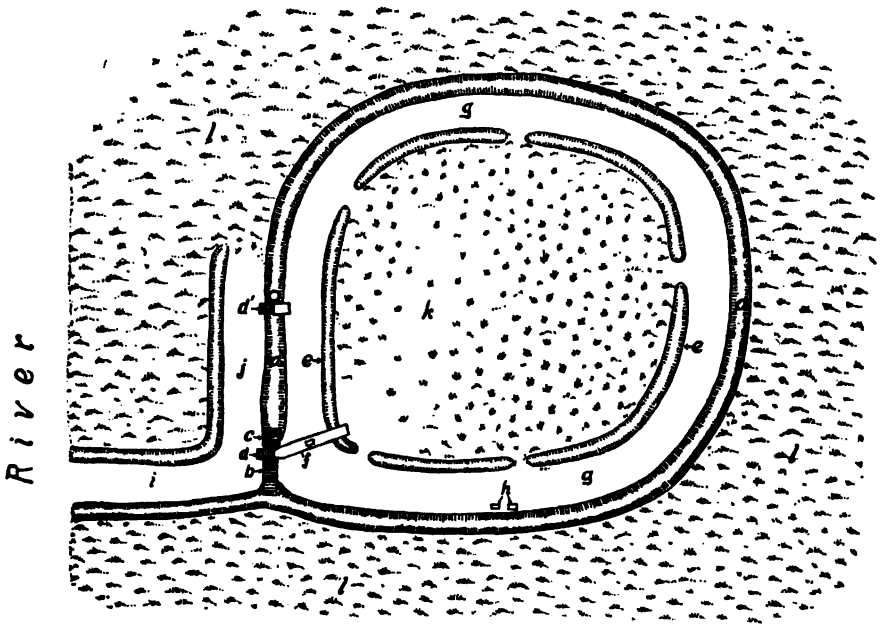


4. Carp in pond at Port Clinton, Ohio, coming up to inflowing stream of fresh water.

CARP PONDS IN LAKE ERIE REGION.

where food is abundant. An exception to this is when a stream of water is pumped in steadily for a time; then the fish begin to come from distant parts of the pond to the place of the incoming stream, as has already been described (p. 560). This tendency of the carp to gather around the place where the fresh water comes in is taken advantage of when it is desired to seine them out, the net being hauled in the dredge cut when the fish have congregated there.

Another pond, near the Raisin River, below Monroe, Mich., and but a short distance from Lake Erie, differs in some ways in method of



Diagrammatic plan of carp pond near Monroe, Mich.: *a*, outer embankment; *b*, dam; *c*, engine house; *d*, *d'*, water elevators; *e*, inner embankment; *f*, chute arranged for carrying water either into dredge cut (*g*) or into central area (*k*); *g*, circular dredge cut; *h*, outlets; *i*, dredge cut from river; *j*, outside dredge cut; *k*, central area (water 1 to 2 feet deep); *l*, marsh (barely covered with water).

construction from the one just described, and for this reason seems worthy of mention. (See fig. above.) This pond is smaller than the other, and is of interest as showing how a pond can easily be built in the middle of an extensive flat marsh. This was done by starting with a dredge at the river and cutting a channel straight into the marsh for a short distance. A large circle was then made, the greater part of the mud brought up being placed on the outer side of the cut, thus forming a high embankment, while on the inner side a smaller one was built up, in which, however, several breaks were left. After it had completed the circle the dredge was taken back outside and a short cut was made on the outside and parallel to the outer embankment. When a dam had now been built at the only opening, it was possible to raise

the water in the interior to a height of 2 or 3 feet above that in the surrounding marsh. This was here accomplished in the same way as at Port Clinton, except that steam power was used for the purpose instead of gasoline engines.

The pond then consists of a ditch 7 to 10 feet deep around the entire circumference, the water over the central area having a rather uniform depth of 1 to 2 or 3 feet. The fresh water that was pumped in was originally turned immediately into the circumferential ditch, or could be carried by a wooden flume over into the central area. The first year the pond was used there was found to be great mortality among the fish, a condition probably due to the large amount of freshly exposed soil with which the water came in contact, so that it became charged with humic acid and other products of organic decay until it was unfit for the fish. This condition continued in spite of the fact that fresh water was continually pumped in, especially during the warmer weather, and it was found later that the water at the bottom of the ditch was very foul and with a bad odor. In the succeeding year flumes were arranged so that the fresh water was carried at once to the bottom of the ditch, and the conditions were found to be much improved. There would probably have been less danger in any case during the second year, as the soil had undoubtedly by that time become very well leached out.

Here, as in the pond previously described, it was found that the fish gathered around the stream of incoming water, and here also advantage was taken of this fact in capturing them. The pond could be drained, if necessary, by changing the elevator over to the inner side of the embankment and discharging the water from the pond back into the surrounding marsh.

There is one other style of pond in use in this region that should be mentioned, in order to make the present account complete. These have been constructed especially by the farmers along the southern shore of Sandusky Bay. They are situated on higher ground than those ponds which have just been described, ground that is usually at least a few feet above the mean level of the bay, and are formed simply by scraping the soil out of an area covering usually not over one-fourth to one-half acre, the soil that is removed being used to build the embankments. The water is supplied by windmills or, in a number of cases, by artesian wells. This water would seem not to be well adapted to carp ponds, being cold and strongly mineral, with a very decided sulphurous taste; and yet the carp are said to do very well in it. As the ponds contain practically no natural food supply, the fish have to be fed regularly to keep them from falling away greatly in weight. For this purpose a variety of things are used, but shelled corn is probably employed more than anything else. In one such pond, which contained about 10 tons of fish, the carp were said to have been fed

very largely upon sowed corn, which was cut when about 1 to 2 feet high and thrown into the pond. The proprietors claimed that the fish would dispose of a load—supposedly a wagonload—of this in four or five days. At this same place the first year the pond was used the fish were not fed at all, and when marketed there was only half the weight of fish that had been put in.

THE VALUE OF CARP PONDS.

It is safe to say that under existing conditions, where at certain seasons of the year three or four men with a seine can obtain adult carp in almost limitless numbers with comparatively little trouble, carp culture in the ordinary sense would not be profitable. At least this is true in regions such as Lake Erie and Lake St. Clair, where carp are so abundant. That regular culture ponds, in which the fish are reared from the egg until of a saleable size, could not be conducted with profit in proximity to some of the large cities which constitute the principal markets for carp is not so certain. Undoubtedly, as the demand for carp grows, as it surely must, such will be the case.

On the other hand, there is no doubt of the great gain to be made by taking carp in the spring and early summer, when they come into the shallows and marshes in such great numbers, and holding them over to fall or winter, when the market price has sometimes multiplied fully tenfold. Let us take, for example, a suppositious case, based, however, on actual conditions. A moderate sized pond could readily accommodate, let us say, 50 tons of carp, and these could be obtained with comparative ease during the spring. At this season, when the fish are most plentiful, the price is often as low as 30 cents per hundred pounds, so that the market value of the whole 50 tons would be but $300, even if they could be disposed of at all at that time; for it often happens that when the fish are so plentiful many more are brought in than can be used, and great numbers bring the fisherman almost nothing, being only sent to be made into fertilizer. Now let us suppose that instead of disposing of these fish at such an unsatisfactory figure the fisherman pens, or otherwise holds them over the summer. Under at all favorable circumstances the loss in that time surely ought not reasonably to be greater than 10 per cent of the total number of fish impounded, even allowing for the damage to fish by handling.

Indeed, in a properly conducted pond, there should be no loss in weight at all. The growth of the living carp, if properly fed and cared for, should adequately offset the loss of individuals. For the sake of fairness, however, we shall assume a loss amounting to 10 per cent of the weight, and that the total weight of fish recovered from the pond in the fall amounted to one-tenth less than that put in—in other words, to 45 tons. Now, in the late summer, fall, and winter months it is not at all unusual for the price of carp to go to 2, 2½, or

even 3 cents per pound, a price ten times as great as that of the spring. Many of the owners of carp in ponds and pens wait only for the market to reach 2 cents per pound, and then fish their ponds and sell the fish. If we market our 45 tons at this moderate price, they now bring us the sum of $1,800, in comparison with which their original value was insignificant.

It is needless to say that not all who make this venture are so successful. From inexperience or ignorance of the conditions required some of the ponds are very unfit for carp, and the mortality is much greater than we have estimated above. Or in some cases, especially in the pens, the fish have no natural food, and they can be maintained in good condition only by feeding them artificially. The cost of this must, of course, be deducted from the profits, and may amount to a considerable item. Furthermore, the initial cost of constructing a pond may constitute a relatively large investment, and account must be made also of the necessary labor to maintain it and to care for the fish. All these items vary greatly with local conditions, for whereas a pond may be constructed and operated very economically in one locality, in another place it may prove very expensive. Certain it is, however, that small ponds are each year proving an acceptable source of subsidiary income to many farmers whose land is favorably located, while individual fishermen and fishing companies are yearly going into this business of holding over carp on a more and more extensive scale.

CONCLUSIONS.

As was stated in the introductory remarks at the beginning of this report, the main purpose of the investigation was to determine, if possible, whether the introduction of the carp into the United States had proved a benefit to the country or whether the fish had turned out to be so detrimental to the fisheries and other interests that it must be considered as a nuisance. In other words, have the twenty-five years or more that the carp has lived in our waters, and in which it has increased to such a surprising extent, justified the belief of those who were instrumental in its introduction that it would fill a place in the economics of our fisheries that could not be taken by any of our native fish; that it could, with little trouble and at small expense, be artificially raised in ponds and other small bodies of water unsuitable for the culture of any equally desirable native species, thus affording a cheap and ready supply of fresh fish to many who would otherwise be unable to have any fish at all; and finally that it would populate such of our lakes and streams as were unfavorable for inhabitation by finer species, and contained only buffalo, suckers, and the like?[a]

[a] The good qualities claimed for the carp, which led to its introduction, will be found enumerated on page 544.

As regards the culture of the carp in this country, we find that, although there was for a few years an enormous demand for the young fish—hundreds of thousands of which were yearly distributed free by the United States Fish Commission and by many of the state commissions—their culture was soon abandoned in nearly all cases and the fish allowed to escape into the open waters of the vicinity. There are a number of reasons to account for this. People were expecting too much. They rushed into carp culture in entire ignorance of the conditions requisite for its successful operation, and, such being the case, it is no wonder that they were disappointed in the results and that their attempts were failures. In the second place, there was also a general disappointment in the qualities of the carp as a table fish. Undoubtedly, as in the case of its culture, too much had been expected, though perhaps not without some justification. Still, the bulletins that had been published and distributed made frequent mention of the muddy flavor of the carp when grown under unfavorable conditions, and emphasized the necessity of keeping such fish for a time in clear water before killing them. Then, too, the fish were often eaten at the wrong season, during the spring and summer months, when their flesh is admittedly poorer in quality than in the fall and winter. This is true of most fish that live in rather shallow and sluggish waters, and even black bass are seldom caught and eaten at these seasons. Perhaps even more important was the matter of cooking. As has been mentioned in the body of the report, it is generally conceded that carp should be cooked in special ways, and the Germans especially have many elaborate dishes which they prepare from its flesh. Most of those who tried the fish here cooked it as they were accustomed to cook our native fishes, and decided that it did not compare favorably with these, though, according to the statements published by Smiley (1886), many appeared to be very enthusiastic about it. Finally, another important factor which probably led to the abandonment of pond culture in many cases was the increasing abundance of carp in the rivers and other open waters. It was found that what fish were wanted could be obtained with less trouble from the open waters than they could be raised.

The whole question was admirably summed up in the Report of the Michigan Fish Commissioners for 1884–1886 (Michigan, 1887, pp. 41, 42). This report not only contained much cool-headed advice to those who were contemplating launching into carp culture, but was almost a prophecy of the outcome of the introduction of carp into the country. After insisting that the carp will not be a success unless properly cared for, the report continues:

From the fact that carp could be successfully grown in warm and muddy waters, it was inferred that they would be just the fish to plant in our comparatively shallow lakes throughout the State, and from the published accounts of their amazing fertil-

ity, and rapid growth, it was confidently expected that in a very short time a large food supply would be furnished.

While we believe that the carp will eventually prove a valuable addition to our food fishes, and especially fill a want amongst the rural population, still we would caution those desiring to engage in this industry to go slow, to test its value for food in comparison with our native varieties; to see whether they like carp to eat before they spend any considerable sums of money in the construction of ponds, etc.

Nothing so much injures any enterprise as overestimating its importance. Estimates are still wanting as to the cost per pound for raising carp, and the fact that they can be so readily procured must in a short time make them so plentiful in the markets as to bring the price below the cost of production, if one-half of those designing to engage in their culture should realize their expectations.

There can be no doubt that the carp is a nutritious and healthy food fish, but there is a doubt whether they will please the taste of the general public who have been accustomed to the taste of our native fish. In the trial made by the Commission and their friends, when direct comparison has been made with our native fish by cooking them in the same manner and at the same time, the decision was that they seemed inferior to the fish with which they were compared, namely, the black bass and the wall-eyed pike. But in the regions where fish, even poor ones, are a luxury they will provide a great boon. In a State so exceptionally well supplied, however, with the finest fresh-water fish in the world, as our State is, it is doubtful if the carp will become either a favorite food or a source of profit for many years to come.

Although the carp did not fulfill expectations in the matter of pond culture, it has more than done so in the way it has adapted itself to conditions found in this country and the rapidity with which it has multiplied in our waters; and we find now that, instead of being generally used throughout the country and especially in those sections where it was thought it would be most appreciated on account of the poverty of the streams or the poor quality of their inhabitants, it is being sold almost entirely to the poorer classes of people in our large cities. The Illinois River, together with the other rivers of the Mississippi drainage system, is one of those localities in which it was thought that carp would be a most valuable accession, and such has turned out to be the case, though not in the exact way originally expected. Although practically not used at all for home consumption, it has nevertheless added very appreciably to the resources of the region.

With our constant immigration of foreigners and the formation and growth in our large cities of great foreign settlements, the problem of supplying these multitudes with cheap yet wholesome food becomes very great, and anything which helps to meet this demand is of great value to the country. From this point of view there is no doubt of the value of the carp and the benefit to be derived from its introduction. To pervert a common saying, in those places to which it is best suited it has made two fish to grow where but one grew before.

But now come the sportsman and the commercial fisherman, who maintain that, while all that has been stated may be true, the presence of the carp is entirely supplanting the fish which was there before,

and that that one fish was of more value than the two carp which have taken its place. This is especially true of such waters as the Great Lakes, and others that were well supplied with good native fish. Furthermore, the sportsmen and others claim that in various ways the carp does more than enough damage to offset its value in other respects. By these persons it is made responsible especially for the great decrease of water-fowl in recent years. These and other charges have been considered in the body of the report, and need not be discussed in detail here. In most cases the reported damage has been either greatly exaggerated or is entirely unfounded. Thus it was found that carp probably have little or no share in causing the decrease of the native fishes commonly taken for sport or for food; and that in the case of the black bass, at least, there is evidence indicating just the opposite—that the bass have actually increased in numbers in some places from having the young carp to feed upon. In the matter of uprooting vegetation, making the water continually roily, and injuring—possibly even completely destroying in some cases—the regular feeding grounds of the migrating ducks—in these cases the evidence goes very largely against the carp, though its effects have undoubtedly, in many instances, been greatly exaggerated, and more has been charged against the fish than it rightfully deserves. In certain places, such as reservoirs and lakes supplying water to cities, etc., there is no doubt that the carp is an unmitigated nuisance, and that its presence is undesirable. Nor can it be considered suitable for the cold, clear lakes of the north, such as are found in northern Wisconsin and in Canada; and fortunately the conditions in these are so unfavorable that it will probably never become so abundant in them as to cause much damage by destroying vegetation and roiling the waters.

Against these charges as to its detrimental influence must be set the things in its favor. Chief among these is that already mentioned—the value of the carp as a source of revenue to the fishermen in the regions where it occurs, and as a cheap food for the poorer class of people who can not afford a better fish. It is impossible to express in dollars and cents the beneficial results and the damage done and thus to compare them directly. The value of the carp fisheries of Lake Erie and the Illinois River region for 1901 was estimated at $342,000 (p. 619, footnote); but there were no data for the rest of the United States. And no monetary value at all can be fixed for the damage done. It seems quite safe to say, however, that if the question were to be considered in this manner the benefits would far surpass the damage. Two other claims in the carp's behalf, which may prove to be of considerable importance, ought also to be mentioned. These are its destruction of the fluke-worm (*Fasciola hepatica*), and of the larvæ of noxious insects, especially mosquitoes. It is possible also that in

rivers, below cities, it may do important service as a scavenger, destroying the germs of certain human diseases, as it does the larval and encysted stages of the liver fluke.

Even were it possible to estimate the money value of the damage done, such a basis would not be an entirely fair one for comparison. Should the carp help to hasten the extermination of any of our water-fowl, or if it destroys the beauty of lakes, as is claimed, this is a harm which can not be reckoned in dollar and cents. As has been pointed out elsewhere, however, there are other and more influential factors at work in the destruction of the water-fowl; and in the other case special measures of prevention and protection must be employed.

And when we have decided whether the carp does more harm than good, we still have the real question before us. The essential problem is this: The carp is here, and here to stay; what are we going to do with it? How can we make the most of its good qualities and prevent it from doing damage? Even were such a course desirable, the extermination of the carp in our waters is out of the question. Mr. Townsend, in some remarks before the American Fisheries Society (Transactions of Thirtieth Annual Meeting, 1901, p. 123) stated the case well when he said:

> We hear a great deal from sportsmen's clubs and from other sources as to how the carp can be exterminated. It can not be exterminated. It is like the English sparrow, it is here to stay. At a meeting of the American Ornithologists' Union a while ago, one of our foremost ornithologists stated that the European sparrow could not be exterminated in this country. I think it is the same with the carp. It is here to stay and we can not exterminate it any more than we can exterminate the green grass of the fields. I do not wish to pose as an advocate of the carp—I prefer other fish for myself—but I maintain that the carp has a place in good and regular standing in our big eastern markets, and I do not think that our great republic with its rapidly increasing population, can afford to sneer at even so cheap a source of food.

In the course of my investigations and inquiries I met frequent propositions that the government, or the respective state governments, should offer a bounty on carp. Nothing could be more futile than this, as has been abundantly illustrated in the case of the English sparrow. The best bounty that can be offered is an increasing market—a growing demand that will make fishing for carp a profitable business. The case in Lake St. Clair is a good illustration. While there I heard the bounty proposition frequently advocated by sportsmen who came to the flats to fish and hunt. But a shrewd resident said, let the state amend the laws so as to allow the taking of carp in nets, and there will soon be enough people fishing for them to reduce their numbers. Since then the laws have been changed so as to allow seining in the lake, and if the removal of enormous quantities of the fish (see p. 614) will do anything toward permanently reducing their numbers, such certainly ought to be the result there now. The lines along which it

seems that the market for carp may in the future be further developed have been pointed out and discussed in the section dealing with its food value and uses.

In another place was mentioned the possible amusement and recreation to be had in taking carp with hook and line. I am aware that the American sportsman will scoff at the very idea, and would regard the pastime with disdain. I wish merely to quote in its defense a paragraph from Goode's American Fishes (Goode, 1888, p. 412), in which he treats of the strenuousness of the average American angler:

> There is a kind of pleasure known to English anglers which is cultivated by but few of those who are called by the same name in America—the quiet, peaceful delight of brook-fishing in the midst of the restful scenery of the woods and the meadows. It is difficult to imagine a thorough disciple of Walton chumming for striped-bass in the surf at Newport or trolling for Muskellunge among the Thousand Islands, drailing for Blue-fish in the Vineyard Sound, or tugging at a tarpum-line in the Gulf of Mexico. The muscular exertion, the excitement, the flurry and noise, make such sports more akin to the fiercer pursuits of hunting than to the contemplative man's recreation. The wisest, best and gentlest of anglers, those who have made the literature of angling akin to poetry, have not, as a rule, preferred to make a violent exercise of their fishing.

Nothing has been said in the present report about protection for the carp in open waters, since, whatever may be the opinion as to the fish's desirability, protection for it does not seem to be needed. I am of the opinion, however, that the phenomenal increase of the carp in those waters where it has been longest will soon reach its maximum, if it has not already done so, and that as the various factors become adjusted a more stable balance will be reached. It is conceivable that then persistent fishing may greatly reduce its numbers.

And now, should I attempt to sum up the principal results of the investigation in a single paragraph, I should say that, whereas the carp undoubtedly does considerable damage, from the evidence at hand it seems reasonable to conclude that this is fully offset by its value as a food fish and in other ways; that it can not be exterminated, and that the problem is how to use it to the best advantage—suggestions for which have been offered. Efforts should be directed to encourage utilization of the fish in all ways possible, since it appears to be a resource as yet comparatively undeveloped.

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DEPARTMENT OF COMMERCE AND LABOR

BUREAU OF FISHERIES

GEORGE M. BOWERS, Commissioner

THE

GERMAN CARP IN THE UNITED STATES

BY

LEON J. COLE

APPENDIX TO THE REPORT OF THE COMMISSIONER OF FISHERIES TO THE SECRETARY OF COMMERCE AND LABOR FOR THE YEAR ENDING JUNE 30, 1904

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